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Effect of Food Plants on the Lesser Migratory Grasshopper[1]

O. L. Barnes, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*[2]

Studies were begun early in 1953 at Tempe, Ariz., to determine the effect of various food plants commonly found in alfalfa fields in southern Arizona on the survival, development, morphology, and fecundity of the lesser migratory grasshopper, *Melanoplus mexicanus mexicanus* (Sauss.). This paper summarizes the results obtained in 1953.

Previous Observations.—Over a period of 18 years, 1936 to 1953, alfalfa fields have been considered the principal cultivated-crop habitat of the lesser migratory grasshopper in the irrigated areas of southern Arizona. The nymphs and adults feed readily on alfalfa, and threatening to very severe infestations have developed frequently in Maricopa, Pinal, and Yuma Counties. The grasshoppers appeared to be endemic to the areas and about normal to above normal in size and vigor. Confidence in the opinion that alfalfa was a suitable host plant was shaken when Brett (1947) in Oklahoma found that alfalfa was a very poor food, when fed exclusively, for survival and development of this species. In tests in Wyoming Pfadt (1949) observed that alfalfa was a poor exclusive food for nymphal development. If this poor response to alfalfa is general, then, how account for the apparently favorable development of this grasshopper in alfalfa fields in southern Arizona? There must be weeds growing in the fields which are favorable food and which supplement the alfalfa so that the mixed diet produces normal to above-normal development.

Brett (1947) found that an exclusive diet of alfalfa produced small adults with abnormally short front wings. Seemingly contrary to this, Gurney (1953) shows a female of normal or above-normal size, with extremely long front wings, that was collected from a lush irrigated alfalfa field near Chandler, Ariz., in 1945. Similar long-winged specimens taken from alfalfa fields are in the collection at Tempe. A female taken near Yuma on November 11, 1936, has front wings 30 mm. long; a female taken at the same location on August 2, 1938, has front wings 35 mm.; and a male from near Tempe on August 31, 1936, has front wings 30 mm. in length. Other long-winged adults of this species were observed infrequently, but not collected and preserved, in the Salt River Valley and Gila Bend areas of Maricopa County and the Yuma area of Yuma County.

For comparison with these long-winged adults, the front wings of 184 males and 156 females that were collected in cultivated areas, mainly in alfalfa fields, in southern Arizona were measured. The wing length of males ranged from 17.0 to 22.8 mm. and averaged 20.4 mm. and that of females from 16.8 to 24.4 mm. and averaged 21.0 mm. The long-winged forms were always collected or observed in alfalfa fields in southern Arizona, and never in other cultivated crops, in northern Arizona, or on rangeland. In addition to the long wings, these adults had bodies of average to above-average size.

In Arkansas, Sanderson (1939) reported that the differential grasshopper, *Melanoplus differentialis* (Thos.), developed faster, had a higher survival rate, and laid more eggs when reared on soybean plants than when reared on cotton. He also found that this grasshopper would not develop beyond the first instar when fed only Bermuda grass. Isley (1942) observed that infestations of the differential grasshopper increased in Arkansas areas where soybeans largely replaced cotton in the farming program. Shotwell (1953) reported that in western Kansas in some years adults of the first generation of the lesser migratory grasshopper were larger than those of the second generation, but that the reasons for the differences were not known. Nabours & Stebbins (1953) in rearing tests with two species of grouse locusts, *Apotettix eurycephalus* Hancock and *Paratettix texanus* Hancock, observed more long-winged forms when development occurred during favorable growing seasons (March to September or October) and more short-winged forms during unfavorable growing seasons (September or October to March). The preponderance of the short-winged form during the unfavorable growing period was ascribed to the shorter days and the resulting deficiencies of light and its accompaniments. Parker (1930) stated that moisture may affect grasshoppers indirectly through their food supply, food of low moisture content tending to produce larger and longer-winged individuals than highly succulent food. He also noted (1937) that several species of grasshoppers have longer wings, slimmer bodies, and brighter colors when reared at high temperatures and fed on partially dried food. Somes (1914) observed in Minnesota that the front wings of the red-legged grasshopper, *Melanoplus femur-rubrum* (Deg.), were unusually long in dry years.

In certain years and at certain locations in Arizona it has been noticed that adults of the second generation of the lesser migratory grasshopper have been smaller

[1] Accepted for publication October 29, 1954.
[2] C. W. McLellan and N. J. Nerney assisted in all phases of the laboratory and field work incident to the investigation.
Miss O. M. Celaya gave much assistance in grasshopper-rearing operations and obtaining oviposition records.

than those of the first generation. This was particularly true in 1944 in the Yuma area. In that year the alfalfa fields were very dry while the second generation was developing and about the only food available was partly dry to dry alfalfa and Bermuda grass. The first generation developed on succulent alfalfa, Bermuda grass, and various late-winter and spring weeds. In 1953, on rangeland of the San Carlos Apache Indian Reservation in eastern Arizona, adults of the second generation were noticeably smaller than those of the first generation. The plant cover consisted mainly of forbs while the first generation was developing, and of grasses while the second generation was developing.

MATERIALS AND METHODS.—All the grasshopper eggs used in the tests were collected from late December 1952 to late February 1953 in a grassy and weedy alfalfa field near Laveen, Ariz. The egg pods were cleared of excess soil, placed over moist sand in salve tins or jars, and incubated at approximately 85° F. in an electric incubator. Within 24 hours after hatching the nymphs were removed to rearing cages and supplied with food. The hatching period extended from early January to early March.

Two types of rearing cages were used—(1) glass tubes 2 inches in diameter by 8 inches long, with the ends covered with cheesecloth held on by rubber bands, and (2) large screen cages 16 by 16 by 14 inches (Fig. 1). Usually 10 nymphs less than 24 hours old were placed in the glass-tube cages and furnished various food plants as follows: alfalfa, Bermuda grass, Johnson grass, nettle-leaf goosefoot (*Chenopodium murale*), a hedge mustard (*Sisymbrium irio*), and a mixed diet of all these plants. Two cages were used for Bermuda grass and three for each of the other plants and the combination diet. The starting dates were February 11, 16, and 24. Average daily temperatures during the tests were: Maxima 82°–84° F., minima 54°–61°, mean 70°–73°. These averages differed with the food plant because of variation in the length of the nymphal period and increasing laboratory temperatures as the season advanced.

Three hundred freshly hatched nymphs were confined in each of four of the large screen cages on March 5 and held there until they died or reached the adult stage.

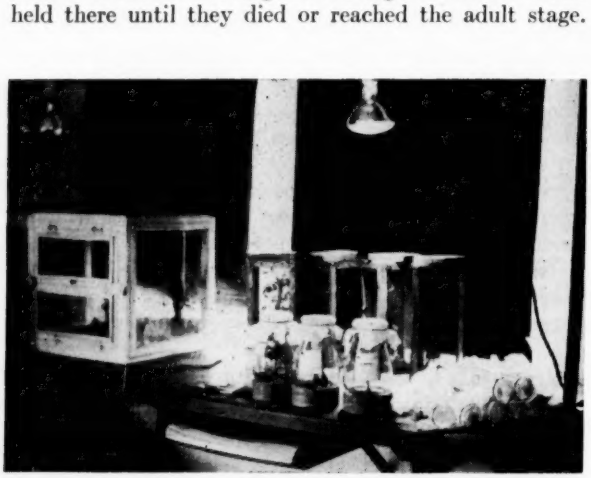

FIG. 1.—Extreme right, small nymphal rearing cages; extreme left, large nymphal rearing cage; center foreground, adult longevity cage.

The nymphs were supplied the following diets: alfalfa; Johnson grass; hedge mustard; and a mixed diet of alfalfa, Johnson grass, and hedge mustard. Average daily temperatures during the tests were: Maxima 85°–90° F., minima 63°–64°, mean 74°–79°.

Adults were held in lantern-chimney cages (Fig. 1) for longevity and oviposition records. The chimneys were set over wood bases, and the tops were covered with cheesecloth held on by rubber bands. During the oviposition period the wood bases were replaced by small flowerpot bases filled with moist sand. One or more males and one female were placed in each lantern chimney cage.

Green leaves and stems of the plants were supplied as food for the nymphs or adults. The food was usually replaced daily. In the large cages the stems of some of the food plants were inserted in vials or bottles of water.

Egg pods were sifted from the sand under oviposition cages and placed in individual salve tins over moist sand for hatching and later egg counts.

The nymphs were reared and the adults and eggs held at room temperatures, with some supplementary heat at night during cool periods from 250-watt infrared lamps suspended over the cages and with some cooling in the daytime during very hot periods by an evaporative-type window cooler. Temperatures were checked as closely as practicable by a thermograph placed near the cages.

Males and females reared on various food plants in large-scale tests were killed in cyanide bottles 4 to 8 days after they reached the adult stage and measured to determine the following ratios: Front-wing length to length of hind femur; length of hind femur to width of head; and length of pronotum to width of pronotum at constriction. The grasshoppers were also dried to constant weight.

RESULTS.—The original plan was to compare alfalfa, Johnson grass, Bermuda grass, and a mixed diet of all three plants as foods for the lesser migratory grasshopper. Johnson grass and Bermuda grass are two of the most common weeds in alfalfa fields in southern Arizona. In early tests involving 456 nymphs furnished Bermuda grass not a single nymph developed beyond the first instar or lived more than 7 days. Some of the nymphs fed sparingly, and the average longevity was about 3 days. However, some of the nymphs fed alfalfa, Johnson grass, or the mixed diet developed to the adult stage. The nymphs also ate and developed on hedge mustard and nettle-leaf goosefoot, two other prominent weeds in alfalfa fields. They fed more readily and made more rapid growth on the mustard.

Small-Cage Rearing Tests.—In these tests, as shown in table 1, the mixed diet was best for both nymphal survival and rapidity of development, followed closely by hedge mustard. Nymphal survival was low and growth slow on an exclusive diet of Johnson grass or nettle-leaf goosefoot. Only one nymph survived to the adult stage on a diet of alfalfa, and its growth rate was slow. None of the nymphs furnished Bermuda grass exclusively developed beyond the first instar, the response being similar to that observed with nymphs of the differential grasshopper by Sanderson (1939). However, adults of the lesser migratory grasshopper have been observed to feed voraciously on Bermuda grass in dry alfalfa fields late in the summer.

Table 1.—Survival and development of nymphs of the lesser migratory grasshopper on various foods in small glass cages.

Food Plant	Nymphs	Nymphs Reaching Adult Stage	Length of Nymphal Period	
			Range	Average
	Number	*Per cent*	*Days*	*Days*
Bermuda grass	20	0	—	—
Alfalfa	30	3	48	48
Johnson grass	30	10	51–55	53
Nettle-leaf goosefoot	30	20	50–62	56
Hedge mustard	30	57	30–38	35
Mixed diet (5 plants above)	30	63	26–40	34

Large-Cage Rearing Tests.—As shown in table 2, the order of suitability for nymphal survival and rapidity of growth was mixed diet, hedge-mustard, Johnson grass, and alfalfa. Johnson grass gave better and hedge mustard poorer results than in the small-cage tests, probably because Johnson grass was more succulent and vigorous later in the season while the hedge mustard was beginning to dry up. With the nymphs fed hedge mustard, Johnson grass, or a mixed diet, there was little difference in the average length of the nymphal period of males and females. With those fed alfalfa the nymphal period was longer for females.

Food Preference of Nymphs.—Daily observations were made on the food preference of nymphs exposed to diets of the green foliage of three to five different plants. Nymphs of all instars were included. Totals of 345 nymphs and 143 daily observations were involved. The amount of feeding on each plant was estimated at the time the food was removed from the cages. The results of the observations are shown in table 3. The order of choice was hedge mustard, far ahead, then alfalfa, Johnson grass, and nettle-leaf goosefoot, with Bermuda grass far behind the other plants.

Further observations on the feeding of nymphs were made in alfalfa fields during April. The nymphs were present in all instars, principally the second to fourth, and populations ranged from 15 to 100 per square yard. Species other than the lesser migratory grasshopper were represented in such small numbers as to be of no consequence. It was easy to observe the feeding of the nymphs and the comparative damage to the different plants. Plants seen growing as weeds in the fields included Australian saltbush (*Atriplex semibaccata*), barley, Bermuda grass, farmer's foxtail grass or mouse barley (*Hordeum stebbinsii*), horseweed (*Erigeron canadensis*), Johnson grass, mallow or cheeseweed (*Malva parviflora*), nettle-leaf goosefoot, prickly lettuce (*Lactuca serriola*), slender oat (*Avena barbata*), sowthistle (*Sonchus oleraceus* and *asper*), and hedge mustard. Heavy feeding and damage were observed on hedge mustard and alfalfa, and these preferred plants were severely injured or defoliated in spots. Feeding on Australian saltbush ranged from light to heavy; in some places this plant was defoliated. There was light to moderate feeding and foliage injury on farmer's foxtail grass, nettle-leaf goosefoot, slender

Table 2.—Survival and development of nymphs of the lesser migratory grasshopper on various foods in large screen cages.

Food Plant	Nymphs Reaching Adult Stage			Length of Nymphal Period (Days)	
	Per Cent	Sex	Number	Range	Average
Alfalfa	8	Male	12	40–62	46
		Female	11	40–74	55
		Both	23	40–74	50
Johnson grass	40	Male	57	33–42	36
		Female	62	29–45	36
		Both	119	29–45	36
Hedge mustard	41	Male	57	26–40	34
		Female	67	26–39	34
		Both	124	26–40	34
Mixed diet (3 plants above)	53	Male	72	25–37	30
		Female	88	25–37	30
		Both	160	25–37	30

Table 3.—Extent of feeding by nymphs on different plants in the laboratory.

Food Plant	Heavy	Moderate	Light	None
Series I (94 daily observations)				
Hedge mustard	41	38	8	7
Alfalfa	6	34	27	27
Johnson grass	3	30	32	29
Nettle-leaf goosefoot	2	13	27	52
Bermuda grass	0	0	5	89
Series II (25 daily observations)				
Hedge mustard	12	10	1	2
Alfalfa	2	13	7	3
Johnson grass	2	9	8	6
Nettle-leaf goosefoot	2	8	7	8
Series III (24 daily observations)				
Hedge mustard	21	3	0	0
Alfalfa	11	9	4	0
Johnson grass	4	9	11	0

Table 4.—Effect of food plants on the longevity of adults of the lesser migratory grasshopper.

Food Plant	Sex	Number of Adults	Length of Adult Period (Days)	
			Range	Mean
Nettle-leaf goosefoot	Male	1	69	69
	Female	5	19–98	74
	Both	6	19–98	71
Johnson grass	Male	7	51–82	66
	Female	7	67–96	78
	Both	14	51–96	72
Alfalfa	Male	4	1–68	43
	Female	3	80–163	114
	Both	7	1–163	78
Hedge mustard	Male	13	37–161	100
	Female	11	52–139	85
	Both	24	37–161	92
Mixed diet[a]	Male	17	27–168	97
	Female	11	21–129	80
	Both	28	21–168	88

[a] Alfalfa, Johnson grass, hedge mustard, and sometimes nettle-leaf goosefoot and Bermuda grass.

Table 5.—Effect of different food plants on the mating, oviposition, and eggs of the lesser migratory grasshopper.

Food Plant	Females								Eggs per Female
	Number	Observed Mating	Laid Eggs	Laid Eggs that Hatched	Pre-oviposition Period	Oviposition Period	Egg Pods per Female		
		Per cent	*Per cent*	*Per cent*	*Days*	*Days*	*Number*		*Number*
Alfalfa	3	0	67	33	65	13	1		13
Nettle-leaf goosefoot	5	0	80	40	49	29	4.6		43
Johnson grass	7	71	100	86	32	24	4.1		89
Hedge mustard	11	64	100	64	31	40	7.8		196
Mixed diet[a]	11	73	91	82	31	49	8.8		221

[a] Alfalfa, hedge mustard, Johnson grass, and sometimes also nettle-leaf goosefoot and Bermuda grass.

oat, and barley. Feeding was extremely light on Bermuda grass, mallow, and horseweed. No feeding was seen on Johnson grass, sowthistle, and prickly lettuce.

Adult Longevity and Egg Production.—Some of the grasshoppers that developed to the adult stage on each of the plant diets in the rearing tests were retained for longevity and egg-production records. Insofar as feasible, the diets fed the adults were the same as those fed the nymphs from which they developed. Hedge mustard dried up about the middle of May, and the surviving adults exposed to this plant were provided a combination diet of alfalfa and Johnson grass for the remainder of their lives. The nymphs molted into the adult stage between February 25 and April 22. Most of the adult period was spent under moderately warm to very warm conditions. Records of mating, egg deposition, and mortality were made daily early in the adult period and later every 2 days. The last adult died on September 24.

Table 4 shows that the order of effectiveness for average longevity was hedge mustard, a mixed diet, alfalfa, Johnson grass, and nettle-leaf goosefoot. It is interesting to observe that the range in mean longevity of the adults fed different plants was rather narrow, 71 to 92 days.

Table 5 summarizes data on mating, oviposition, and egg viability. The best results were obtained with the females fed a mixed diet. Although not shown in the table, one of the females fed this diet deposited 20 pods containing 437 eggs. Of the single food plants, hedge mustard was the best, almost equaling the mixed diet. The females fed Johnson grass were in third place. Females fed alfalfa exclusively made the poorest showing of all.

Size and Body Dimension Ratios of Adults.—The average body dimensions and dimension ratios, according to food plant and sex of adults, are shown in table 6. The measurements and ratios were lowest in the adults reared on alfalfa. Second lowest measurements were in the group reared on Johnson grass. Adults reared on hedge mustard had the largest measurements, which were very similar to the measurements of the adults reared on a mixed diet. There was little difference in the ratios between body measurements of the adults reared on Johnson grass, hedge mustard, and a mixed diet, except that the adults reared on Johnson grass had a lower ratio of femur length/head width than those reared on hedge mustard or a mixed diet. If it is assumed that large size of adults and high ratios between the three pairs of body dimensions shown in the table indicate a tendency toward the migratory phase (Rocky Mountain grasshopper), then the adults reared on hedge mustard or a mixed diet were most advanced in their progress toward the migratory phase, those reared on Johnson grass somewhat less advanced, while those reared on alfalfa showed little or no development toward the migratory phase and were the most typical of the solitary phase (lesser migratory grasshopper).

Table 6.—Effect of various food plants on certain body dimensions of migratory grasshopper adults.

Food Plant	Sex	Number	Length of Front Wings (mm.)	Length of Hind Femur (mm.)	Ratio Front Wing Length/ Hind Femur Length	Width of Head (mm.)	Ratio Femur Length/ Head Width	Pronotum Length (mm.)	Pronotum Width (mm.)	Ratio Pronotum Length/ Pronotum Width
Alfalfa	Male	6	16.6	10.3	1.63	3.6	2.94	4.3	3.2	1.36
	Female	6	16.3	10.3	1.57	3.5	2.93	4.1	3.1	1.31
Johnson grass	Male	50	21.5	12.7	1.69	4.2	3.04	5.2	3.6	1.45
	Female	56	21.8	13.4	1.64	4.2	3.15	5.3	3.9	1.37
Hedge mustard	Male	51	22.2	13.3	1.68	4.1	3.23	5.4	3.7	1.46
	Female	61	23.0	14.2	1.63	4.4	3.25	5.8	4.2	1.37
Mixed diet (3 plants above)	Male	65	22.1	13.3	1.66	4.2	3.18	5.4	3.8	1.43
	Female	71	22.7	14.0	1.62	4.3	3.25	5.6	4.0	1.40

It should be noted that the average length of the front wings of adults reared on hedge mustard or the mixed diet exceeded 22 mm. Shotwell (1930) found that the largest adult collected in northern Montana had front wings 22 mm. long, and he stated (1953) that the average length of the front wings did not exceed 20.53 mm. on adults collected in Montana in 1927 or 21.37 mm. on adults collected in Kansas in 1941, 1951, and 1952. Although not indicated in table 6, some of the females reared on hedge mustard or a mixed diet had front wings 25 mm. long. Brett (1947) observed that some individuals reared on head lettuce had front wings 24.6 mm. long, and commented that this was equal to the average for the migratory phase of this grasshopper. The adults reared on hedge mustard or a mixed diet including hedge mustard had unusually long front wings, some of them as long as those of adults known to belong to the migratory phase.

The average dry weights of adults reared on different food plants are shown in table 7. The adults reared on hedge mustard or a mixed diet were largest and about equal in weight. Adults reared on Johnson grass were 80 to 85 per cent as heavy. Those reared on alfalfa were very small, weighing approximately one-half as much as adults reared on hedge mustard or the mixed diet. In figure 2 typical adult females reared on alfalfa, Johnson grass, and hedge mustard are compared with an extremely long-winged female collected from an alfalfa field near Yuma, Ariz., in 1936.

DISCUSSION.—The results of these tests indicate strongly that alfalfa, when fed exclusively during the active period, is an unfavorable food for normal or vigorous development and reproduction of lesser migratory grasshoppers. On this diet the nymphs grew slowly and survival was very low. The adults were much below normal in size, laid few eggs, and lived for a shorter period than adults fed a more favorable diet. Moreover, their body proportions were more typical of the solitary phase than were those of the adults reared on Johnson grass, hedge mustard, or a mixed diet of alfalfa, Johnson grass, and hedge mustard. The results suggest the possibility that the lesser migratory grasshopper might not be able to maintain itself through a number of generations on alfalfa alone.

In view of these indications and since it was not possible to rear the species on an exclusive diet of Bermuda grass,

Table 7.—Dry weights of adult lesser migratory grasshoppers reared on different food plants.

FOOD PLANT	SEX	NUMBER	AVERAGE WEIGHT (mg.)
Alfalfa	Male	5	50
	Female	8	58
Johnson grass	Male	49	92
	Female	52	96
Hedge mustard	Male	46	105
	Female	55	119
Mixed diet (3 plants above)	Male	62	105
	Female	65	115

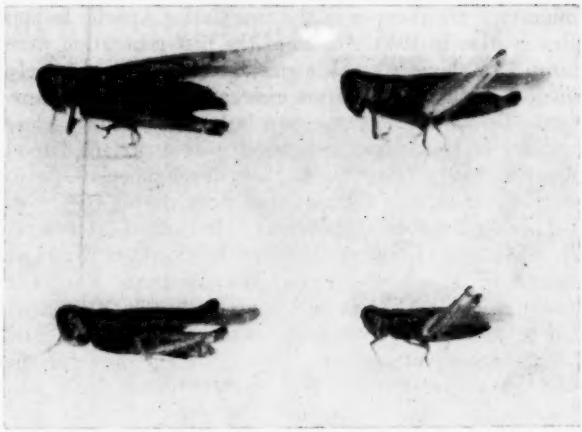

FIG. 2.—Lesser migratory grasshopper females, showing comparative differences in size and wing length. Upper left, extremely long-winged form collected in an alfalfa field near Yuma, Ariz.; upper right, typical specimen reared on hedge mustard; lower left, typical specimen reared on Johnson grass; lower right, typical specimen reared on alfalfa.

it is not surprising that the second-generation grasshoppers in the Yuma area in 1944, which were limited to an almost exclusive diet of drying to dry alfalfa and Bermuda grass, were much below normal in size. In July 1952 near Litchfield Park, Ariz., a threatening population of the lesser migratory grasshopper in early nymphal instars in an 80-acre alfalfa field practically disappeared in a very short time, for no apparent reason. The only plants available in the field were alfalfa and Bermuda grass. It seems possible that the limited diet was inadequate for maintenance of the population.

The poor showing of alfalfa as an exclusive food for the lesser migratory grasshopper appears to be due to some nutrient deficiency rather than to the presence of any harmful substance. When alfalfa was included in a mixed diet with hedge mustard, a very favorable food plant, and Johnson grass, a moderately favorable food plant, and comprised a substantial portion of the total food consumed, the growth, longevity, and egg production were at least as great as when the diet was hedge mustard or Johnson grass exclusively.

Of the individual plants tested as foods for the lesser migratory grasshopper, the hedge mustard produced adults that were larger, laid more eggs, and had body dimensions and proportions more closely approaching the Rocky Mountain grasshopper than were produced by any of the other foods. It seems likely that this weed, either alone or supplemented by alfalfa and other forbs and grasses, would furnish an adequate diet for development of the lesser migratory grasshopper under field conditions.

The tests in 1953 indicated that Johnson grass and nettle-leaf goosefoot would serve as sustenance during periods when the more suitable and palatable food plants are scarce or absent. It is doubtful if they would, either singly on in combination, support a slowly increasing population.

Under "Previous Observations" reference was made to the small size of second-generation adults of the lesser

migratory grasshopper in the San Carlos Apache Indian Reservation in 1953. Adults of the first generation were normal to above normal in size. They developed largely on forbs, alfilaria (*Erodium cicutarium*), and tansymustard (*Descurainia obtusa*), the last plant being a close relative of hedge mustard, which was a preferred food plant and very favorable to their development. Grasses were dominant and forbs scarce or dry during the growing period of the second generation. In the tests at Tempe, Bermuda grass would not support the growth of the lesser migratory grasshopper, and Johnson grass was only moderately suitable. It seems probable, therefore, that the ready availability of suitable forbs in the spring and their scarcity late in the summer may account for the fact that the adults of the first generation were larger than those of the second generation. The type and condition of available food plants may have been one of the factors responsible for the differences in the size of the first- and second-generation adults of the lesser migratory grasshopper in Kansas, observed by Shotwell (1953).

SUMMARY.—At Tempe, Ariz., alfalfa, Bermuda grass, Johnson grass, nettle-leaf goosefoot, and hedge mustard were compared as foods for the lesser migratory grasshopper, *Melanoplus mexicanus mexicanus* (Sauss.).

Nymphs fed Bermuda grass exclusively died before reaching the second instar.

In small-cage rearing tests nymphs survived best on hedge mustard, followed by nettle-leaf goosefoot, Johnson grass, and alfalfa. They grew most rapidly on hedge mustard, followed by Johnson grass, nettle-leaf goosefoot, and alfalfa. Survival and rate of growth were increased slightly on a diet of all these plants over that obtained on an exclusive diet of hedge mustard.

In large-scale rearing tests the percentages of nymphal survival were as follows: hedge mustard, 41, Johnson grass, 40, alfalfa, 8, and mixed diet, 53. The average lengths in days of the nymphal period were 34 for hedge mustard, 36 for Johnson grass, 50 for alfalfa, and 30 for the mixed diet.

The order of food plant preference of nymphs was hedge mustard, alfalfa, Johnson grass, nettle-leaf goosefoot, and Bermuda grass.

The rank of the plants for producing longevity of adults was hedge mustard, alfalfa, Johnson grass, and nettle-leaf goosefoot, with a range from 71 to 92 days.

The average egg production per female was 221 on a mixed diet, 196 on hedge mustard, 89 on Johnson grass, 43 on nettle-leaf goosefoot, and 13 on alfalfa.

On the basis of adult body measurements specimens reared on alfalfa were the most typical of the solitary phase and those reared on hedge mustard the most divergent from that phase. Adults were progressively smaller when reared on hedge mustard, a mixed diet, Johnson grass, nettle-leaf goosefoot, and alfalfa.

Alfalfa exclusively is apparently a very unfavorable diet for the lesser migratory grasshopper, as compared with a mixed diet or an exclusive diet of such weeds as hedge mustard or Johnson grass. Weed control might reduce populations in alfalfa fields, particularly in large alfalfa-growing areas when long-distance migrations are not involved.

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Control of Adult Tabanids by Aerial Spraying[1]

A. W. A. Brown[2] and P. E. Morrison,[3] *Veterinary and Medical Entomology Unit, Entomology Division, Ottawa, Canada*

Horse flies of the genera *Tabanus* (*Hybomitra*), locally called moose flies, and *Chrysops*, known as deer flies, are very abundant in the forest zone of Canada northward to the tree line. At Goose Bay, Labrador, where the studies reported in this paper were carried out, their activity is largely confined to the month of July. On warm days during that period their annoyance to animals and man may become almost unbearable.

The success of large-scale aerial spraying from Dakota aircraft for mosquito and black-fly control in Canada (Brown 1952) prompted investigation of the effects on adult tabanids of similar extensive treatments with the chlorinated hydrocarbon insecticides DDT, lindane, and dieldrin. Previous attempts to use DDT against tabanids had been somewhat inconclusive. Treatment of salt-marsh shore lines in Massachusetts with two successive sprayings of DDT at 1 pound per acre from a helicopter achieved 95 per cent reduction of the adult population of *Tabanus nigrovittatus* Macq. (Gerry 1949). However, attempts to reduce the numbers of adults of *T. sulcifrons* Macq. and *T. abactor* Phil. by treating 10- and 60-acre plots in Oklahoma woodland with DDT, methoxychlor, toxaphene, and chlordane at 2 pounds per acre were all unsuccessful (Howell *et al.* 1949).

Biological Conditions.—The experiments were carried out in 1952 and 1953 at the air base at Goose Bay, Labrador, on a sandy plateau above numerous sphagnum bogs margined by swampy woods and separated by scrubby black spruce forest. The seasonal occurrence of tabanids was similar for 1952 and 1953. They first appeared in small numbers on June 25 and were represented by *Tabanus metabolus* McD. and *Chrysops excitans* Wlk. On July 7, *C. carbonaria* Wlk. appeared and became very abundant by July 10; on this date *T. zonalis* Kby. also appeared and reached maximum abundance on July 17. Adults of *T. metabolus* did not persist beyond July 15, or those of *C. excitans* beyond July 22. July 15 was the date of first appearance of *T. typhus* Whit., which became very abundant a week later; a similar species, *T. astutus* O. S., appeared on July 23 and was most abundant on July 30. These two species were the only tabanids to persist into August, numbers still being present on August 10. During July, *C. mitis* O. S., *C. sordida* O. S., *C. frigida* O. S., and *C. furcata* Wlk. each constituted less than 1 per cent of the population, and single specimens of *T. hearlei* Phil. and *T. septentrionalis* Loew were taken on July 30. Adult tabanid populations were brought to large numbers in 1952 by a period of hot weather between July 7 and 11, and in 1953 by warm weather beginning on July 8. In both years populations were at high levels between July 8 and July 27.

The population of adult tabanids was assessed by its activity as indicated by the landing rate on small tents made of black mercerized cotton cloth. The tops and three sides of the tent supports were covered with the cloth, and the fourth side was left open (Fig. 1). In 1952, the tents were 3 by 3 by 3 feet; in 1953, card tables 30 by 30 by 26 inches were used. They were placed in open spaces in the woods; after a waiting period of 15 minutes, a count was made of the landing rate of tabanids on each tent. Three men, one observing the top and one side, another the remaining two sides, and a third the interior through the open side, counted the number of landings and strikes made by these flies during a period of 3 minutes. Individuals of the genus *Chrysops* landed more frequently than those of *Tabanus*.

Fig. 1.—Method of assessing landing rates of tabanids on a black-covered tent.

An activity index was computed from a continuous series of counts on a single tent in a clearing adjacent to the areas sprayed. In 1952 it was covered on the top and two sides and remained at the same spot each day. In 1953, the top and three sides were covered and it was set up in one of three clearings according to the area sprayed. A single observer counted the landing rate on the top and two sides for 3 minutes, and a minute later repeated the operation. The average of 10 successive counts gave the activity index for the 40 minutes concerned. At each count, the air temperature, cloud cover, and wind speed were noted.

The activity indexes are plotted against air temperature in figure 2, to which they show a significant correla-

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[2] Head, Department of Zoology, University of Western Ontario, London, Canada; in the seasonal employ of the Entomology Division as Entomologist when this work was performed.

[3] Assistant Entomologist.

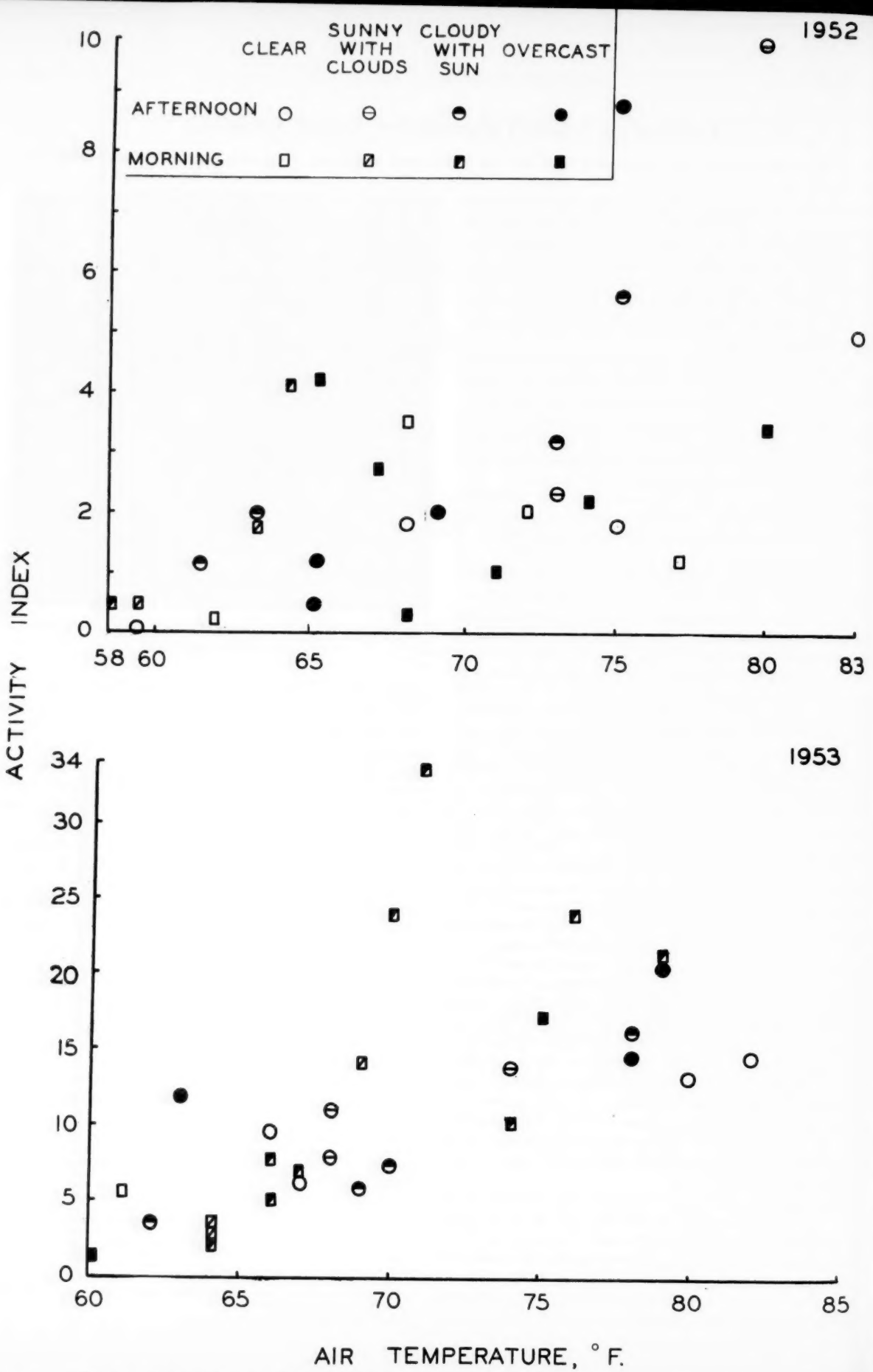

FIG. 2.—Activity indexes of adult tabanids in relation to air temperature, cloudiness, and time of day.

tion ($r=0.59$ for the 1952 and 0.64 for the 1953 values). The lower activity indexes of 1952 are attributable to the smaller area of the tents for the counts. The cloud cover and time of day are also indicated in this figure, but there is no apparent correlation of the activity indexes with these factors. The highest activity indexes were obtained under conditions of high overcast or slight cloud cover, characteristic of warm fronts, rather than in full sunlight. Activity almost ceased when the air temperature fell to 60° F., even in full sunlight. It appeared therefore that sunlight played a secondary role to air temperature in determining tabanid activity, although it had the effect of increasing the air temperature. Wind did not enter as a factor in the woods unless the free wind speed exceeded 20 m.p.h., when it commenced to decrease the tabanid activity.

MATERIALS AND METHODS.—The insecticidal materials used were: a 25 per cent concentrate of DDT in alkylnaphthalene (Sherwin-Williams, Montreal, Que.); a 20 per cent concentrate of lindane in a mixture of 32.5 per cent alkylnaphthalene and 40 per cent isophorone, with 7.5 per cent emulsifier (Kolker Chemical Works, Newark, N. J.); and an 18 per cent concentrate of dieldrin dissolved in xylene, with 5 per cent emulsifier (McConnon and Co., Winona, Minn.). The diluent consisted of No. 2 fuel oil (Imperial Oil Ltd., Toronto, Ont.).

For each application of insecticide, a plot 1 mile square was chosen, one of its sides being used as a starting line for 18 parallel flights 100 yards apart. Spraying was performed with the Dakota (C-47) aircraft at a speed of 150 m.p.h.; the flying height was normally 100 feet above the treetops, being increased to 200 feet in light winds. The aircraft was fitted below the fuselage with a single rotary brush unit (I-C-D, Series 800) carrying two 8-inch brushes alternating with three 10-inch ones, driven by a 50°-pitch propeller; this arrangement emitted at 1.05 imperial gallons per second a spray whose mass median diameter was 180 microns (Brown 1952).

The 18 miles of emission flight over each plot required 432 seconds, during which time 450 imperial gallons were expended. This load was evenly divided between the two 250-gallon tanks in the fuselage. The concentration of the insecticide was adjusted so that the correct dosage resulted. For example, a dosage of 1 pound of DDT per acre required 640 pounds of insecticide, obtained from 256 gallons of a 25 per cent concentrate and diluted with 194 gallons of fuel oil, making a 14.2 per cent spray.

Seven of the treatments were applied in the afternoon, four in the evening, and one in the morning. Pre-spray tabanid assessments were made 1 to 3 hours before the application; in most instances one or more preliminary assessments were made earlier on the day of spraying or on preceding days. Post-treatment assessments were usually made 1 hour after the application, and were repeated at intervals of 1 or 2 days during the period of reinfestation. For each assessment, five tents were set out at intervals of 100 to 300 feet along a line running through the center of the plot and at right angles to the lines of flight.

In most instances observers were stationed in the middle of the plot during the application. In 1953, before each treatment performed at 0.25 pound per acre (Table 4), tabanids were caught and tethered to branches by means of yellow nylon thread tied around the bases of their abdomens. After the spray had fallen, these flies, along with others found still flying in the area, were placed in screen-topped pint cardboard sealers for observation.

In parallel laboratory experiments in 1953, the insecticides were applied in a spray tower by the method of Brown *et al.* (1948), the mass median diameter of the droplets being approximately 60 microns. To allow a sufficient quantity of liquid to be accurately dispensed in the spray tower, the insecticide concentrates were diluted with fuel oil so that the concentration of insecticide was one-fifth of that employed in the field experiments; e.g., a 2.84 per cent solution was used for a dosage of 1 pound per acre, and 1.18 ml. was applied over the area of 118 square inches at the base of the tower. The tabanids were collected in the field shortly before use, and were anesthetized with carbon dioxide; it is noteworthy that they recovered from this anesthesia too rapidly for convenience. Groups of 10 to 30 individuals of *Tabanus typhus* were placed in random postures on a sheet of paper, rapidly sprayed, and promptly transferred to screen-topped pint sealers for a 6-hour observation period. Groups of 10 adults of *Chrysops excitans* were similarly treated at the single dosage of 0.25 pound per acre, given by 0.6 ml. of 1.42 per cent solutions of DDT, lindane, and dieldrin.

In addition, topical application tests were performed by the method of Ludvik (1953). A 0.25-ml. syringe was used with a No. 26 B. & D. needle bent at right angles and cut square at the end. DDT, lindane, and dieldrin, purified by recrystallization, were prepared in 1 per cent solutions by dissolving 500 mg. in 15 ml. of acetone and making up to 50 ml. with 95 per cent aqueous ethanol. When *Tabanus metabolus* was treated, 0.5 ml. containing 5 micrograms of insecticide was applied to the venters of the abdomens of groups of 20 to 30 flies. The average weight of an adult of *T. metabolus* being 67 mg., the dosage level was 75 mg. per kg. The stock used contained 19 per cent of *T. zonalis*, their average weight being 135 mg. Groups of 10 individuals of *Chrysops excitans* were similarly treated with 3 micrograms of insecticide. After treatment, the adults of *T. metabolus* were kept in cages of approximately 27 cubic feet capacity, with three sides covered with black cotton cloth and the fourth side and the top with plastic screening, the cages being left in the woods for 14 to 18 hours. The adults of *C. excitans* were placed in pint sealers covered with plastic screening and kept in the laboratory for 6 hours.

Table 1.—Mortality of *Tabanus typhus* in spray-tower experiments.

Insecticide	Concentration (Per Cent)	Equivalent Dosage (Lbs./Acre)	No. of Insects Used in Each Test	Percentage Mortality	
				3 hr.	6 hr.
DDT	0.71	0.25	29	28	79
	1.42	0.5	23	44	87
	2.84	1.0	15	60	93
Lindane	0.71	0.25	9	78	89
	1.42	0.5	9	89	100
	2.84	1.0	16	100	100
Dieldrin	0.71	0.25	6	67	83
	1.42	0.5	12	83	100
	2.84	1.0	20	70	100
Check		(fuel oil)	11	0	9

Table 2.—Effect on *Tabanus metabolus*[a] of topical application of 5 micrograms of insecticide in aqueous acetone-alcohol.

Insecticide	Number of Insects			
	Dead	Moribund	Ataxic	Normal
3 to 4 hours after treatment				
DDT	0	2	8	10
Lindane	15	2	4	2
Dieldrin	0	3	2	22
Check	1	0	1	19
14 to 18 hours after treatment				
DDT	17	3	0	0
Lindane	19	4	0	0
Dieldrin	24	3	0	0
Check	12	1	0	8

[a] The sample treated contained 19 per cent of *T. zonalis*.

Results.—The mortalities of *Tabanus typhus* obtained in the spray tower experiments are shown in table 1. Lindane knocked down all the flies within 5 minutes, whereas the knockdown with DDT and dieldrin was not complete until 2 hours after spraying. Lindane gave in 3 hours a degree of mortality for which DDT and dieldrin required 6 hours. At these times any flies still living were lying on their backs and capable of moving only their legs. The mortalities of *Chrysops excitans* at the single dosage of 0.25 pounds per acre with DDT, lindane, and dieldrin were respectively 50, 100, and 40 per cent after 3 hours, and 90, 100, and 100 per cent after 6 hours.

The results of the topical application tests are shown in table 2. The effect of lindane on these species was immediate and violent agitation, quickly followed by knockdown; the majority were dead in 3 hours. DDT and dieldrin were much slower in causing restlessness, and no mortality occurred in 3 hours. After 14 to 18 hours, all three insecticides had caused almost 100 per cent mortality; despite the high mortality in the check, chi-square analysis showed that all the insecticide mortalities were significant at the 5 per cent level. The mortalities of *Chrysops excitans* treated with 3 micrograms of DDT, lindane, and dieldrin were respectively 40, 60, and 20 per cent after 3 hours, and 80, 100, and 40 per cent after 6 hours.

In the field experiments, the flies in the sprayed area showed the following effects of the insecticides at 0.25 pound per acre. Lindane immediately excited the tabanids; *Chrysops* spp. ceased flying within 15 minutes and *Tabanus* spp. within 30 minutes. DDT made both groups noticeably more sluggish in flight within 30 minutes after spraying. Dieldrin made *Chrysops* more sluggish, but *Tabanus* became excited and slightly ataxic in flight.

Flies that were tethered in the plots during the spraying gave the following results. The mortalities with lindane after 2 hours were approximately 60 per cent for *Chrysops* spp. and 40 per cent for *Tabanus* spp.; those with DDT after 4 hours were 20 per cent for both groups, but 20 to 30 per cent were moribund and the remainder were sluggish (*Chrysops*) or ataxic (*Tabanus*). The mortalities with dieldrin after 4 hours were 50 per cent for *Chrysops* spp. and 25 per cent for *Tabanus* spp., but in both instances 20 to 30 per cent were moribund and the remainder either sluggish (*Chrysops*) or ataxic (*Tabanus*).

The post-spray assessments of all 12 plots, after correction of the landing rates by the activity index, are given in table 4 as percentages of the pre-spray level. An example of the way in which these figures were derived is shown in table 3, which gives the data for a plot sprayed with lindane at 0.5 pound per acre; the results for the 11 other plots were treated similarly. The total landing rate on the five tents exposed is corrected by the activity index to give the population figure. The landing rate figure of 149 obtained at the last pre-spray assessment, when the activity index was 13.9, serves as the initial population figure. All other landing rate figures are corrected by the activity index to conform with this figure. For example, in the last post-spray assessment a landing rate of 213 was obtained when the activity index was 33.7; when corrected this gives a population figure of $213 \times 13.9/33.7 = 88$. It may then be computed that the population had recovered to 59 per cent of its pre-spray level (i.e., 88 is 59 per cent of 149).

Table 3.—Data concerning aerial spraying of 1 square mile of open spruce swamp with 0.5 lb. per acre of lindane against adult tabanids, Goose Bay, Labrador, 1953[a].

Date	Hour	Weather	No. of Strikes and Landings on Tent					Total	Activity Index	Population Figure	Population Per Cent
			A	B	C	D	E				
July 9	11:30 A.M.	72°, 7/10 stratus	33	26	24	18	28	129	11.5	156	
July 9	2:00 P.M.	74°, 2/10 cumulus	13	37	46	19	34	149	13.9	149	(100)
July 9	4:30 P.M.	63°, high overcast	0	0	0	0	0	0	12.0	0	0
July 10	10:30 A.M.	60°, high overcast	0	0	0	0	0	0	1.5	0	0
July 11	6:00 P.M.	62°, 9/10 overcast	1	1	0	0	0	2	3.6	8	5
July 12	12:15 P.M.	78°, 7/10 cloud	10	4	22	32	27	95	21.2	62	42
July 15	11:15 A.M.	71°, 8/10 cloud	12	21	36	52	92	213	33.7	88	59

[a] Spray applied on July 9 at 4:00 P.M.

Table 4.—**Post-spray landing rates, corrected by the activity index, expressed as percentages of last pre-spray landing rate.**

	Dosage (Pounds per Acre)											
	DDT					Lindane				Dieldrin		
	0.25	0.5[a]	0.5	1.0[a]	2.0[a]	0.25	0.5[b]	0.5	1.0[a]	0.25	0.5	1.0
Pre-spray landing rate, number	513	55	213	493	681	69	149	94	107	128	104	161
Post-spray landing rate, per cent												
1 hour	40		47			35	0	18	0	35	92	28
1 day	60	0	81	8	33		0	46		32	71	9
2 days		73	151		27	65	5	119	0	70		
3 days	45			143			42					91
4 days		33		160		224			37			
6 days							59					
10 days					55							

[a] Tests in 1952, others 1953.
[b] Applied over dense woods with undergrowth.

Lindane was the most effective of the insecticides tested. At 0.5 pound per acre, tabanids were eliminated for 2 days from open spruce forest or muskeg, but in dense spruce forest with alder underbrush there was only 82 per cent reduction. At this dosage lindane sprays required less than 30 minutes to take full effect. Although the odor of the isophorone solvent was noticeable on first encounter, men were able to work in the sprayed area without discomfort or after-effects. A dosage of 0.25 pound per acre was insufficient for decisive results even in the open forest.

DDT gave temporary reductions of 53 to 100 per cent at dosages up to 2 pounds per acre. There was no evidence that deposits on vegetation had any residual effect. The dosage of 0.25 pound per acre, as routinely applied for adult mosquito control, temporarily reduced the population figure by approximately one-half.

No significant reduction in activity was obtained with dieldrin unless the dosage was raised to 1 pound per acre. At the lower dosages, the stimulative effect of this insecticide on *Tabanus* spp. made the tabanid annoyance appear greater than before the spray applications.

Discussion.—The field experiments showed that only lindane gave 100 per cent reduction, though temporary, in landing rates of adults of *Tabanus* and *Chrysops* spp., whereas DDT and dieldrin did not give satisfactory reduction. Yet in the laboratory experiments DDT and dieldrin were as toxic as lindane, although much slower in action. The generally higher mortalities obtained in the laboratory tests are probably partly due to the exposure to insecticide of parts of the body normally protected by the wings, and the lower mortalities in the field may partly derive from the ability of the flies to shelter under vegetation. The slowness of action of DDT and dieldrin would allow time for the tabanids to enter the sprayed area from the outside before the full population reduction had been achieved. It must also be emphasized that the dosage level of 75 mg. per kg. topically applied to *T. metabolus* is considerably higher than the LD_{50} levels for *Musca domestica* L. and *Aedes aegypti* (L.), which are below 10 mg. per kg. (David 1945, Perry & Hoskins 1951).

The variation in the population figures, as set out in table 4, is a consequence of the great mobility of tabanids and the extreme dependence of their activity upon weather conditions. This activity appeared to depend primarily on air temperature in the region of Goose Bay, Labrador. Miller (1951) found at Churchill, Manitoba, that the highest average activities were encountered in the temperature range of 68° to 73° F., but that activity increased continuously as the light intensity increased.

Summary.—Laboratory and field tests were made of lindane, DDT, and dieldrin as adulticides for Canadian forest species of *Tabanus* and *Chrysops*. The laboratory tests showed all three insecticides to be toxic, lindane being much the fastest in action. Aerial application of 0.5 pounds of lindane per acre to plots 1 mile square with a Dakota (C-47) aircraft fitted with a rotary brush unit temporarily eliminated tabanids in open but not in dense forest. Temporary but unsatisfactory reduction was obtained with DDT at 0.25 to 2 pounds per acre. Negligible reduction was obtained with dieldrin at 0.5 pound per acre, and temporary reduction at 1 pound per acre.

Populations were assessed on the basis of landing rates on tents of black cloth. Tabanid activity varied widely with weather conditions, depending principally on air temperature.

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Effect of Clothing Color on Mosquito Attack on Exposed Skin[1]

A. W. A. Brown,[2] *Veterinary and Medical Entomology Unit, Entomology Division, Ottawa, Canada*

Attention has been given to the development of protective clothing against mosquito attack in Canada, and the color has been a prime consideration. Bright cloths are the least attractive, and dark cloths, or more precisely those that have minimum reflectivity in the range between 475 and 625 millimicrons wavelength, are the most attractive (Brown 1954). Thus black, dark blue, and red are attractive, whereas white, green, and yellow are unattractive colors. The question remained whether an unattractive garment would decrease the attack on the face and hands of the wearer, or increase it by discouraging the mosquitoes from landing on the garment itself.

Four types of clothing were tested. Two were attractive cloths, namely, a black drill coverall and a serge "air force blue" battledress. The other two were unattractive, being a white drill coverall and a green nylon "insect suit." The garments were compared with each other in pairs, and no head covering was worn. The tests were performed in spruce forest at Goose Bay, Labrador; the wearers stood 6 feet apart, two observers confining their attentions to one wearer at a time. One observer counted the number of landings of mosquitoes on the back from waist to shoulders (14 by 16 inches), and the second simultaneously counted the number of mosquitoes landing to bite on the face (7.8 by 5.5 inches), including the fronts of the ears. After these counts had been made, the observers moved immediately to the second wearer, who had been standing in position. In a test, these counts were replicated four times on each wearer, the positions being interchanged after every replicate and the clothing being interchanged after two replicates. The duration chosen for each count in a comparison was 1 minute; however, when the population of mosquitoes was low, the duration of each count was increased to 1.5 minutes, and in one instance to 2 minutes. Each pair of clothing types was subjected to four tests, with four different pairs of wearers. At the time (June 25 to July 6, 1953) the mosquitoes were abundant, and consisted mainly of the species *Aedes communis* (Deg.), *A. punctor* (Kby.), *A. pionips* Dyar, and *A. fitchii* (F. & Y.).

The results of the comparisons of each garment with the three others are shown in table 1. From this table it might be observed that in all of the four tests (each with four replicates) between attractive and unattractive cloths, the total numbers of landings on the face, as well as on the back, were lower with the unattractive cloths (green and white) than with the attractive cloths (blue and black). However, an analysis of variance applied to the landing rates on the face showed no significant difference at the 5 per cent level except in the case of black versus white, where the difference was significant at the 1 per cent level; and Student's *t* test applied to the landing rates on the back showed a significant difference only with blue versus green.

Table 1.—Landing rates of *Aedes* spp. on backs and faces of wearers of clothing of four colors, two unattractive and two attractive.[a]

Comparison	Back		Face	
	Total of 4 Tests	Count on First Color as Percentage of Total	Total of 4 Tests	Count on First Color as Percentage of Total
Green : White (unattractive)	54: 76	42	56: 66	46
Green : Blue	89:167	35	75: 83	47
Green : Black	66: 94	41	102:117	47
White : Green (unattractive)	76: 54	58	66: 56	54
White : Blue	76:109	41	100:118	46
White : Black	48: 66	42	88:118	43
Blue : Green (attractive)	167: 89	65	83: 75	53
Blue : White	109: 76	59	118:100	54
Blue : Black	105: 89	54	92:127	42
Black : Green (attractive)	94: 66	59	117:102	53
Black : White	66: 48	58	118: 88	57
Black : Blue	89:105	46	127: 92	58

[a] Each comparison is listed twice for purposes of exposition.

Comparison of these results with the more decisive differences obtained with headless robots (Brown 1954) suggests that the presence of the face is a complicating factor for the landing rate on the body. The figures in table 1 indicate that the ratio between the landing rate on the face and that on the back was higher with unattractive clothing (1.21) than with attractive clothing (1.01), and thus suggest that the expected diminution in the swarm around an unattractively clothed person is partially negated by a greater portion of the swarm proceeding to the face.

From the data obtained in these experiments, it is concluded that lighter-colored clothing does not increase the attack of mosquitoes on the face, although a significant decrease was obtained only with white versus black.

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[1] Contribution No. 3236, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada. The results herein reported were obtained by the Entomology Division in a program of studies on the biology and control of biting flies being carried out on behalf of the Defence Research Board, Canada Department of National Defence, and with the co-operation of that organization and other agencies. Accepted for publication September 2, 1954.

[2] Head, Department of Zoology, University of Western Ontario, London, Canada; in the seasonal employ of the Entomology Division, as Entomologist when this work was performed.

The assistance of P. E. Morrison, Assistant Entomologist, and B. E. Lanning and J. E. P. Trudel, Survey Assistants, Veterinary and Medical Entomology Unit, Ottawa, in these experiments, at great personal discomfort, is gratefully acknowledged. The author is indebted to D. G. Peterson, Associate Entomologist, also of this unit, Ottawa, for performing the statistical analyses.

Differential Susceptibility of the Sexes and Developmental Stages of the American Cockroach to Several Insecticides[1,2]

DONALD G. COCHRAN

In most of the studies on the development of acquired insect resistance to insecticides little reference is made to the effect of sex or stage of development on the resistance of an individual insect. This is probably to be expected because much of the information came from field work in which all insects in a treatment area would receive as nearly as possible the same dose of toxicant regardless of sex or developmental stage. From a number of laboratory investigations, however, some information has been forthcoming on this subject. For example, it has been reported that female house flies are naturally more resistant to DDT than are males in both susceptible and resistant strains of flies (Barber & Schmitt 1948, Bruce & Decker 1950, Busvine 1951). Grayson (1951) found a similar situation in resistant and susceptible strains of the German cockroach, *Blattella germanica* (L.). With the latter species the resistant females possessed extremely great acquired resistance whereas the males were only moderately resistant.

In carrying on laboratory selection for DDT resistance in a beneficial parasitic wasp, *Macrocentrus ancylivorus* (Hymen), Pielou & Glasser (1952) found that the females of this species also developed greater resistance than the males. Similarly, Heal (1942) working with some of the older insecticides (arsenicals, NaF, etc.) found them to be naturally more toxic to the male than to the female American cockroach, *Periplaneta americana* (L.), regardless of method of application. Munson & Gottlief (1953) obtained similar results with DDT.

In an investigation dealing with the role of both sex and developmental stage in susceptibility, Ricci (1948) found that male and female nymphs and adult females of the oriental cockroach, *Blatta orientalis* L., were all more resistant to DDT than adult males.

MATERIALS AND METHODS.—In the present study adult male and female American cockroaches were compared in their natural susceptibility to the following chlorinated hydrocarbon insecticides: lindane, chlordane, toxaphene, dieldrin, methoxychlor, and DDT. Last instar male and female nymphs were compared with adult females in their susceptibility to DDT. In all cases the cockroaches were injected with known amounts of toxicant by means of a micro-injection machine equipped with a 27-gauge hypodermic needle. The solvent used to carry the toxicants was a mixture of 10 parts of xylene, 10 parts of acetone, 75 parts of deobase, and 5 parts of absolute ethyl alcohol. This mixture was found to be less toxic at a given concentration than several other materials tested. The actual injections were carried out while the cockroaches were immobilized by mild anesthesia

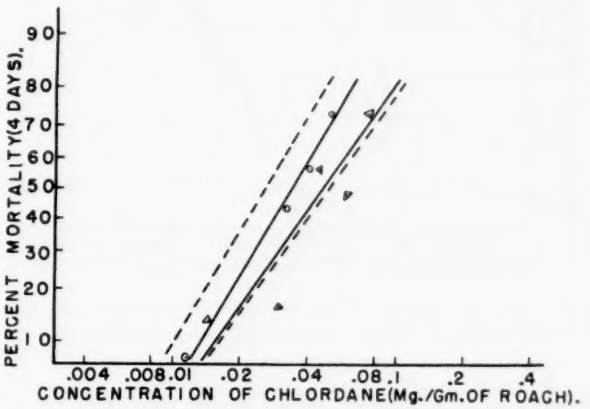

FIG. 2.—The toxicity of injected chlordane to adult male and female American cockroaches. Circles, males; triangles, females.

[1] This work was done while the author was a T. J. Headlee Research Fellow at Rutgers University, and is a part of the doctorate thesis submitted to the graduate faculty in partial fulfillment of the degree requirements.

[2] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology, New Brunswick. Accepted for publication October 25, 1954.

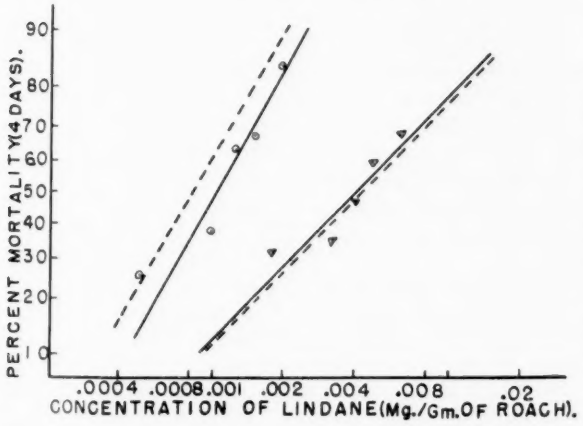

FIG. 1.—The toxicity of injected lindane to adult male and female American cockroaches. Circles, males; triangles, females.

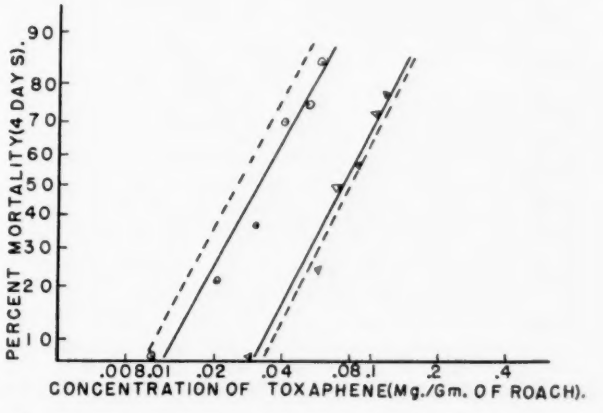

FIG. 3.—The toxicity of injected toxaphene to adult male and female American cockroaches. Circles, males; triangles, females.

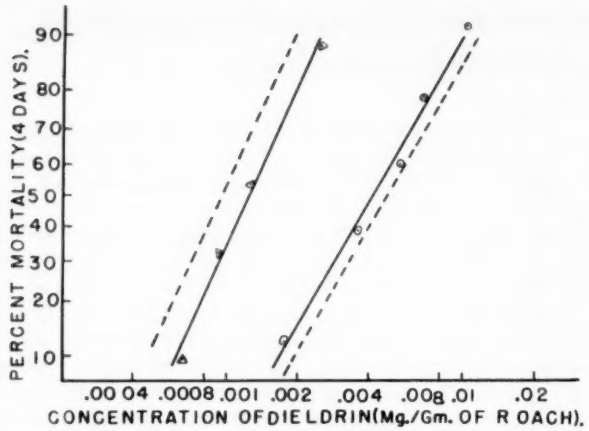

FIG. 4.—The toxicity of injected dieldrin to adult male and female American cockroaches. Triangles, males; circles, females.

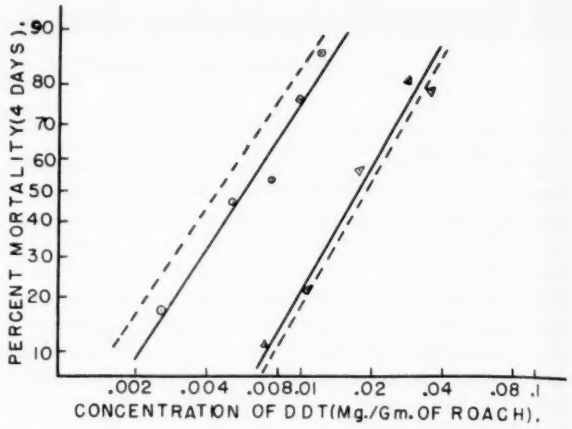

FIG. 6.—The toxicity of injected DDT to adult male and female American cockroaches. Circles, males; triangles, females.

with carbon dioxide gas which greatly facilitates injecting. The toxicants were introduced into the blood-stream of the thoracic cavity through the membranous area on the ventral surface immediately anterior to the subcoxa of the right metathoracic leg and close to the lateral edge of the body. Insects injected with only the solvent mixture were used as controls in each experiment.

Following injection the treated insects were kept in 1-gallon battery jars in a constant temperature room (22° C.). Drinking water was provided in these jars in small containers. Mortality counts were made on the cockroaches daily for 4 days and the number of impaired individuals noted. The criterion used to indicate death was failure to exhibit active locomotion.

RESULTS.—The data are presented in the form of dosage-mortality curves prepared according to the method of Bliss (1935). They were fitted by eye only. Each point on each curve was replicated from three to five times with each replicate usually consisting of 25 cockroaches. In each of the figures 1 through 6 the dotted lines represent the data as they were taken (mg. of toxicant/cockroach), while the solid lines are the same data expressed as milligrams of toxicant per gram of cockroach tissue. With the data on the effect of DDT on the adult females and last instar male and female nymphs, however, only the data expressed as milligrams of toxicant/gram of cockroach tissue are given (Figure 7). It was found that these data expressed as milligrams of toxicant/cockroach differed only very slightly from the form in which they are given and both sets of data on the same graph would have been too confusing. Therefore, only the more significant data are shown.

From a comparison of figures 6 and 7, it can be seen that the LD_{50} values of adult females in the two figures vary slightly. In figure 6, this value is 0.020 mg., while in figure 7, the corresponding value is 0.032 mg. The data for figure 7 were taken several months after that for figure 6 and this serves very well to point out that the vitality of the laboratory strain varies from time to time. It does not mean that one set of data is less reliable than the other.

An attempt was made to determine if there is a common factor among the various insecticides tested by

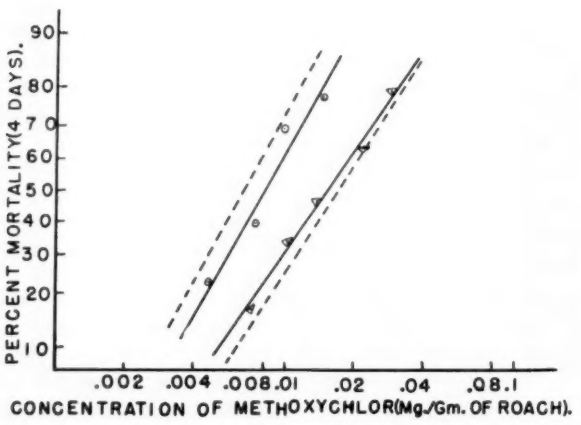

FIG. 5.—The toxicity of injected methoxychlor to adult male and female American cockroaches. Circles, males; triangles, females.

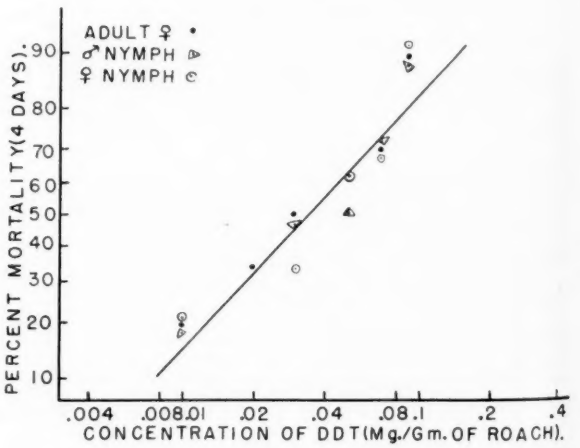

FIG. 7.—The toxicity of injected DDT to adult female and last instar nymphal male and female American cockroaches.

Table 1.—Male and female LD_{50} data.

INSECTICIDE	MALE LD_{50}	FEMALE LD_{50}	X[a]
	mg.	mg.	
Lindane	0.0008	0.0044	5.5
Dieldrin	0.001	0.005	5.0
DDT	0.0045	0.020	4.4
Toxaphene	0.025	0.080	3.2
Chlordane	0.026	0.052	2.0
Methoxychlor	0.007	0.018	2.5

[a] Factor by which female LD_{50} exceeds male LD_{50}.

which the LD_{50} of the females is greater than the LD_{50} of the males. In the equation male $LD_{50} \times$ = female LD_{50} $\times$ is the factor. The data are presented in table 1.

It can be seen from the preceding data that the adult female was normally less susceptible than the adult male to the effects of all six of the insecticides tested. This seems to be in general agreement with the work of others as mentioned earlier. However, the percentage superiority of the female apparently varies with the toxicant. Although some of the factors given in table 1 are in close agreement, great variation exists and consequently based on these data there appears to be no general rule applicable to chlorinated hydrocarbons as a group. With the last instar nymphs the sexual difference in susceptibility apparently does not hold. In fact, no discernible difference could be found between adult females, male nymphs, or female nymphs with respect to DDT susceptibility (figure 7). This also seems to be in general agreement with the information in the literature (Ricci 1948).

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Vapor Heat Sterilization of California Citrus and Avocado Fruits against Fruit-Fly Insects[1,2]

WALTON B. SINCLAIR and D. L. LINDGREN, *Citrus Experiment Station, Riverside, California*

The method of treating fruit with moist heat to destroy eggs and larvae of fruit flies was originally developed and used in Florida to sterilize citrus fruits against the spread of the Mediterranean fruit fly, *Ceratitis capitata* (Wied.). According to Baker *et al.* (1944), the vapor heat process was perfected in Florida in 1929 during the program directed against the eradication of the Mediterranean fruit fly. The first experiments in which latent heat of saturated vapor was utilized for the sterilization of fruits infested by fruit-fly larvae were performed in Florida by Yothers and his assistants under Baker's direction. Subsequently, the commercial application of this process was carried out in Texas under the direction of Hawkins (1932).

As a result of the eradication campaign against the Mediterranean fruit fly in Florida, more than 5,000 cars of citrus fruits were successfully treated by this method. In accord with the quarantine regulations, the vapor heat method (saturated vapor at 110° F.) is, at this writing, the prescribed treatment for sterilizing shipments of oranges and grapefruit from areas in which the Mexican fruit fly, *Anastrepha ludens* (Loew), is known to occur.

With the discovery of the oriental fruit fly, *Dacus dorsalis* Hendel, in the Hawaiian Islands in 1946, it became apparent that all possible steps should be taken to prevent the introduction of this species to the mainland. The California legislature, realizing the importance of the problem, authorized the University of California to participate in a program of investigation along with the U. S. Bureau of Entomology and Plant Quarantine and other interested agencies.

If the oriental fruit fly should be found in California, quarantine restrictions would be issued immediately, and treatments for the sterilization of various commodities against this insect would be instituted. Treatments of this nature are being developed by the Entomology Research Branch, U. S. Department of Agriculture in Honolulu. However, owing to the numerous kinds of host fruits in California the use of a given method of sterilization would depend upon the capacity of a specified fruit variety to withstand the treatment.

The three methods of sterilization used are refrigeration, fumigation, and moist heat at a high temperature

[1] PAID PAPER, accepted for publication Jan. 3, 1955.
[2] Paper No. 837, University of California Citrus Experiment Station, Riverside.

(110° F.). The present report is concerned with the tolerance of citrus and avocado fruits to saturated atmospheres at 110° F. and 120° F. for specified periods. The results of the fumigation experiments are reported elsewhere.

Inasmuch as the vapor heat method has been authorized and was used to sterilize fruits and vegetables against the various fruit-fly infestations that had occurred in the past, it was natural, therefore, that this treatment should be immediately recommended on discovering the oriental fruit fly, *Dacus dorsalis* Hendel, in the Hawaiian Islands. It was found early in these experiments, however, that certain varieties of fruits were not tolerant to the exposures to kill all stages of the fly. This was especially true of citrus and avocado fruits. Although this method of treatment has been used with some degree of success on Valencia oranges and grapefruit (Baker *et al.* 1944), some varieties of citrus, such as the navel orange and the lemon, were severely injured, and the quality and flavor of the juice were significantly lowered.

The main object of the present investigation has therefore been to determine to what extent the vapor heat method can be applied to California-grown citrus and avocado fruits without injuring the fruit, lowering the composition or altering the flavor of the juice. The problem is complicated not only by varietal differences but also by seasonal differences, by differences in time of fruit maturity, and by variations in individual fruits and in the environments in which they are grown. With these variables in mind, the task involves the heating of the different varieties of fruit at the required temperatures in saturated atmospheres for a specified time, and the subsequent storage of the fruit for a designated period so that the development of injury may be noted.

MATERIALS AND METHODS.—Citrus fruits (Valencia and navel oranges, grapefruit, and lemons) for these experiments were obtained from packing houses in the different citrus-growing districts of California. Each experimental sample consisted of from 10 to 30 boxes of orchard-run fruit, and the fruit was treated in the picking boxes without cleaning or segregation.

Avocado fruits (Fuerte and Dickinson varieties) were obtained from the California Avocado Association. Each sample consisted of from 10 to 30 flats—the fruit treated in the packed flats with the tops removed.

Total soluble solids were determined with an Abbe refractometer. Total acidity, expressed as citric acid, was determined by titrating an aliquot portion of the juice with a standard solution of NaOH with phenolphthalein as an indicator. The pH values were determined with a Beckman glass-electrode pH meter.

The vapor heat method used in these experiments was the procedure approved by the Bureau of Entomology and Plant Quarantine for treating fruits and vegetables for interstate movement from Hawaii (B.E.P.Q. 481, Revised, Hawaiian Fruit and Vegetable Quarantine No. 13). It consisted essentially in heating the fruit to 110° F. in saturated vapor. In most of these experiments, the fruits being treated were exposed to saturated vapor and the temperature gradually raised over a period of 8 hours until the temperature at the center of the fruit reached 110° F., and this temperature was maintained for an additional 8¾ hours. Saturated vapor was maintained in the chamber for the entire period of 16¾ hours. In the latter part of our investigations, the approach period, that is, the 8 hours required for the sample to reach 110° F., was considerably reduced. The mortality of the eggs and larvae of the various fruit flies is dependent upon the latent heat released when water vapor is condensed on the surface of the fruit.

In some of the experiments, the sterilization process was performed by a modified vapor heat method which is commonly called the "quick run-up" method. Although the same principle of heat transfer is involved, the method consists essentially in exposing the commodity to saturated vapor at 120° F. and subsequently removing the product when it reached an internal temperature of 119° F. As shown by other investigators, the mortality of the oriental fruit fly was complete at 119° F. The chief advantages of this method are that the time of exposure of the commodity to high temperatures is greatly reduced, and that the time required for the product to reach 119° F. depends on the heat capacity of the chamber and the size of the load. With citrus and avocado fruits, approximately 4 hours were required to reach this temperature.

ESTIMATING EXTERNAL PHYSICAL INJURY TO THE FRUITS.—The external physical injury of the heat-treated fruit was determined by observing each individual fruit in both the control and treated samples. These observations were made on the treated samples between 24 and 48 hours after removing them from the heating room. The samples were run through the regular packing-house procedures and subsequently placed in storage for observation of evidence of external and internal breakdown of the fruit. The degrees of injury were listed as slight, medium and severe. This method of classification was found to be useful in allocating relative differences in fruit response to heat treatment. From a practical or commercial standpoint, this type of data is not particularly important, for fruit that received any peel collapse or surface injury as a result of the vapor heat treatments would be rejected as a product for the fresh fruit market. Consequently, the values that represent the total percentage of injury reveal the practical information that is desired.

EXPERIMENTAL ROOM FOR VAPOR HEAT STERILIZATION OF CITRUS AND AVOCADO FRUITS.—The vapor heat experiments required a room with equipment to control the heat, relative humidity and circulation of the air in the room. An experimental lemon storage room with an individual air washer was used for installation of the necessary equipment. An immersion steam-heat coil of 1-inch standard pipe was installed in the air-washer pan which had the capacity to raise the temperature of the water in the pan to 180° F. when using 20 pounds of steam, and which heated a 1000 C.F.M. of air to 150° F. wet bulb and to nearly 100 per cent relative humidity. Within the room, reheating coils constructed of 6 Wolverine finned ½-inch I.D. tubes were installed, two banks deep, in front of the supply air outlets. This coil had sufficient capacity to raise the temperature of the air from 150° F. to approximately 180° F. dry bulb.

An automatic control system of the Johnson Service Co. was used for operating an open steam coil valve on the fin-type dry reheat coil to maintain its setting in relation to a second controller operating a normally open

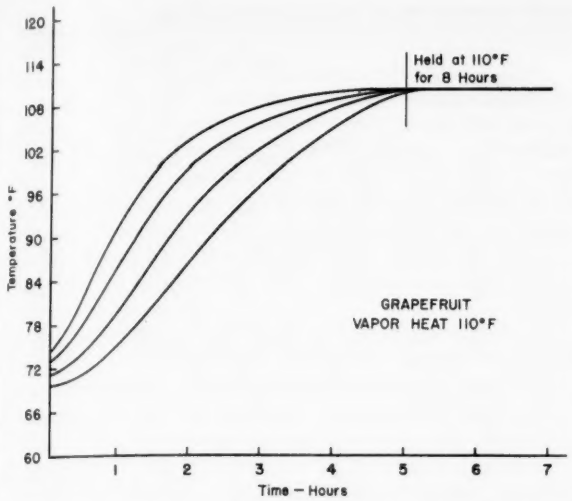

FIG. 1.—Fruit temperatures in relation to time required to attain 110° F. at approximate center of fruit.

steam valve controlling the immerse steam coil in the air-washer pan.

This equipment proved efficient in heating this room (10×16×10 feet) to 120° F. together with 40 fifty-pound boxes of fruit and automatically holding this or other predetermined temperatures and recording the temperatures and dew point with the room.

During the vapor heat treatment, fruit temperatures were determined by means of copper-constantan thermocouples made from 30-gauge wire, tightly wound and soldered at the junction. The temperatures were recorded by a Leeds and Northrup Speedomax recorder. Twelve different temperatures were recorded in fruits which were placed in different locations within the chamber. The thermocouples were inserted in the fruit by means of udder needles in which the thermocouples were placed prior to insertion. This made it simple and easy to get thermocouples to the center of the fruit. Usually, the thermocouples were placed in fruits located in the center of the box. Temperatures were read from the charts to the nearest degree.

THE APPROACH PERIOD IN THE VAPOR HEAT TREATMENT OF CITRUS FRUITS.—Figure 1 shows graphically the rise in temperature of 15 boxes of grapefruit to 110° F. during an approach period of 5 hours in a saturated atmosphere. The slopes of the curves indicated the relative rates of heating of grapefruit when thermocouples were placed in the approximate center of the fruits and the latter were placed in the center of the various orange shipping boxes which contained the fruit. The rates of heating the fruit were also influenced by the type of container in which the fruits were placed. Thus fruit placed in ventilated containers such as orange shipping boxes heated more quickly and evenly than fruit packed in solid-wall containers such as lemon picking boxes. In these experiments, fruit boxes were separated in the chamber so that the hot, moist air could circulate and pass around and through the boxes. Under a given set of conditions, the rates of heat conduction of citrus fruits are related to the heat capacity or specific heat of the fruit and size of the fruit.

EFFECT OF HEAT STERILIZATION ON INJURY TO CITRUS FRUITS.—The data reported in table 1 show the effect of vapor heat sterilization on the development of peel injury to citrus and avocado fruits. Experimental results are reported for both the 110° and 120° F. methods for sterilizing fruits and vegetables against infestations of fruit fly larvae. The number of experiments are given for each group of data, and each experiment consisted of from 10 to 30 boxes of fruit.

It can be readily observed that navel oranges are severely damaged by the vapor heat treatments. The amount of injury which occurred on late navels (April 7 to May 16, 1950) was highly significant at the 1 per cent level. Other sterilization experiments showed that early mature navels (January 2 to April 26, 1951) withstood the heat treatments better than the late-season fruit. The total injury noted for the 110° and 120° F. treatments, respectively, was barely significant at the 5 per cent level.

The Valencia orange variety was not significantly injured by the vapor heat treatments. Apparently, the Valencia orange withstood the moist heat treatments better than any of the other varieties studied in this investigation. The Valencia peel is more resistant to the marked surface blemishes that occurred so abundantly in the treated navel oranges.

Grapefruits of good, sound quality were not seriously injured with the heat treatment in saturated atmosphere at 110° F. for 8 hours. The grapefruits that received the so-called "quick run-up" treatment at 120° F. were significantly injured under these conditions. The results on grapefruit did not indicate that all of the grapefruit samples were injured by the 120° F. vapor heat treatment; such was not the case, for some of the samples withstood the treatment exceedingly well. The data did indicate, however, that peel collapse and breakdown occurred in some of the experiments as the result of the 120° F. treatment.

Similar experiments were carried out on lemons. Both heat treatments injured lemon fruits. The surface injury on the lemons was not quite as great as in the navel oranges, but the off-flavor in the lemons was considerable. The heat-treated fruit did not store well as shown by the accelerated internal breakdown during the 3 weeks' storage period, at 58° F. and 80 per cent relative humidity. During the storage period, the treated lemons were more readily attacked by fungi than the control fruit.

EFFECT OF HEAT STERILIZATION ON INJURY TO AVOCADOS.—Avocado fruits (the Fuerte and Dickinson varieties) were sterilized by the vapor heat methods in order to determine their tolerance to high-temperature treatments. It was immediately found that avocados would not tolerate a 16-hour treatment in a saturated atmosphere at 110° F. Similarly, avocados could not tolerate saturated vapor at 120° F. as prescribed by the "quick run-up" method (Table 1).

All avocados were damaged by the vapor heat treatments. The injury to the fruit consisted of off-flavors, rancid odor, and darkening of the interior. These injuries were intensified on storing the fruit at 50° F. for 1 week. The high moist temperatures of the vapor heat treat-

Table 1.—Effect of heat sterilization on the subsequent development of injury to citrus fruits.

Variety	Treatment ° F.	Dates Treated	Number of Experiments[a]	Degree of Injury			
				Slight	Medium	Severe	Total
				Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
Navel Oranges	110	4- 7-50 to 5-16-50	15	22.8	10.7	8.7	42.3[c]
	110	1- 2-51 to 4-26-51	21	6.2	1.4	.7	8.3[b]
	120	1- 2-51 to 4-26-51	11	6.1	.9	1.0	8.0[b]
Valencia Oranges	110	6-12-50 to 7-13-50	8	3.8	1.3	.3	5.4
	110	8-14-50 to 10- 5-50	13	1.9	.1	3.0	5.0
	120	8-15-50 to 10- 4-50	13	2.8	.3	.5	3.6
Grapefruit	110	6-19-50 to 4-10-51	14	3.5	2.4	1.3	7.2
	120	7-17-50 to 4-10-51	12	7.1	6.2	4.2	17.5[c]
Lemons	110	5-15-50 to 4-18-51	17	8.1	3.3	1.3	12.7[c]
	120	9-28-50 to 12- 1-50	13	5.4	7.6	1.7	14.8[c]
Special group lemons graded twice							
1st grading	110	11-14-50 to 11-21-50	4	5.2	1.4	1.2	7.8[b]
2nd grading	after 3 weeks in storage at 58° F. and 80 per cent R.H.			3.5	8.9	26.3	38.8[c]
1st grading	120	11-13-50 to 11-20-50	2	8.6	2.4	2.9	13.9[c]
2nd grading	after 3 weeks in storage at 58° F. and 80 per cent R.H.			6.1	0.0	19.7	25.8[c]
Avocados	110	10-11-50 to 11- 9-50	6	0.0	0.0	98.6	98.6
	120	10-16-50 to 11-10-50	8	0.0	0.0	99.6	99.6

[a] Each experiment consisted of from 10 to 30 boxes of fruit.
[b] Significant at the 5 per cent level.
[c] Significant at the 1 per cent level.

ments appeared to inactivate the enzyme systems of the avocado fruits to the extent that treated fruit failed to ripen normally. In storage the treated fruits were readily attacked by fungi and, consequently, deteriorated very rapidly.

EFFECT OF HEAT STERILIZATION ON THE CHEMICAL COMPOSITION OF CITRUS FRUITS.—The chemical reaction of citrus varieties to the vapor heat process was made by determining the changes in some chemical constituents of the fruit (Table 2). In this study, a comparison of heat-treated and control samples was made on the bases of the total soluble solids, titratable acidity, ascorbic acid and comparative changes in pH of the centrifuged juices.

The heat treatments did not produce a significant decrease in the total soluble solids of the juice of citrus fruits. In most of the heat treatments a marked reduction occurred in the titratable acidity of the juice. The percentage decrease in titratable acidity varied from 7.9 per cent in Valencia oranges to 20.3 per cent in nave

Table 2.—Effect of heat sterilization on the chemical composition of citrus fruits.

Variety	Treatment ° F.	Dates Treated	Number of Experiments	Decrease in		
				Soluble Solids	Titratable Acid	Ascorbic Acid
				Per Cent	*Per Cent*	*Per Cent*
Navel Oranges	110	4- 7-50 to 5-16-50	15	.1	13.6[b]	9.7[b]
	110	1-21-51 to 4-26-51	21	1.9	18.7[b]	3.6[b]
	120	1-21-51 to 4-26-51	11	1.6	20.3[b]	2.9[b]
Valencia Oranges	110	6-12-50 to 7-13-50	8	.5	7.9[b]	0.3
	110	8-14-50 to 10- 5-50	13	1.2	9.9[b]	5.4[b]
	120	8-15-50 to 10- 4-50	13	.9	10.4[b]	3.4[b]
Grapefruit	110	6-14-50 to 7- 6-50	10	2.6	13.0[b]	5.9[b]
	120	7-17-50 to 7-27-50	8	1.5	18.6[b]	7.5[b]
	110	3-28-51 to 4-10-51	4	5.3	10.3[b]	4.8[b]
	120	3-28-51 to 4-10-51	4	6.0	19.1[b]	4.6[b]
Lemons	110	5-15-50 to 5-23-50	4	7.9[a]	14.5[b]	18.7[b]
	110	9-27-50 to 11-30-50	8	4.1	11.2[b]	0.9
	120	9-28-50 to 12- 1-50	6	4.3	8.3[b]	3.2[b]
	110	2-19-51 to 4-18-51	5	.6	9.2[b]	3.5[b]
	120	2-19-51 to 4-18-51	3	.2	8.3[b]	8.6[b]

[a] Significant at the 5 per cent level.
[b] Significant at the 1 per cent level.

oranges. The significant decreases in free acidity were caused, in all probability, by the increased respiration of the fruit at these relatively high temperatures.

As a result of the vapor heat treatments, the amount of ascorbic acid was usually significantly less in the treated fruit. In comparison with the control samples, the reduction in ascorbic acid of the treated samples varied from 0.29 per cent in a series of Valencia experiments to 18.66 per cent in a group of lemon experiments. From a nutritional standpoint, the decrease in vitamin C of the treated fruit is especially objectionable to the consumers of fresh citrus fruits.

The reduction of free acids in the heat-treated fruits produced a corresponding increase in the pH values of the juice samples. In table 3, pH values are listed for the control and treated samples of citrus fruits. The heat treatments produced a significant increase in pH of the juice from the treated fruits over the control samples.

EFFECT OF HEAT STERILIZATION ON THE FLAVOR OF CITRUS FRUITS.—Taste tests were made on all heat-treated samples. The first test was made after the fruit had been stored at room temperature for 24 hours. In order to determine the effect of storage on fruit flavor, other taste tests were made at intervals during the storage period.

The fresh delicate flavor of the navel orange was destroyed by the vapor heat treatments. In comparison with the control samples, the fruit had a flat, "musty" taste. The flavor resembled that of fruit which had been in storage for some time. During the storage period, some of the off-flavor which was characterized by this "mustiness" disappeared, but the fresh "bouquet" flavor characteristic of fresh fruit was permanently destroyed.

The fresh flavor of the Valencia orange was also partially destroyed and the off-flavor readily detected by the fresh fruit experts of the industry, but the degree of off-flavor in the Valencia variety was not as great as that which occurred in the navel orange.

In many instances differences in flavor could be detected in treated grapefruit. In the injured samples, the fruit had a distinct anaerobic flavor. As a result of the decrease in free acidity during the heating process, the less acid fruit was readily discerned by the taste test. It should be noted, however, that off-flavors, as measured by the taste test, were not as great in the grapefruit and Valencia orange varieties as in the navels and lemons.

The lemon samples which were injured in the heat treatments also possessed anaerobic off-flavors. The treated lemon samples which developed internal breakdown during subsequent storage developed extremely bad off-flavors. As a result of the development of off-flavors, a large percentage of this fruit was not acceptable for by-products after heat sterilization.

DISCUSSION.—It must be realized that the effect of these two heat treatments on the fruit is markedly influenced by the variety of the fruit, the environment in which it is grown, the degree of maturity and the quality of the fruit at the time the experiments are performed. All of these factors are highly important in the successful operation of the vapor heat process for sterilizing citrus fruits against fruit-fly larvae and eggs. These factors are definitely manifested in the response of the navel orange variety to heat sterilization. Navel oranges grown in the Covina and Glendora districts of California have extremely soft and tender peels. As a result of the excessive soil moisture and of rainy weather, the peel becomes turgid and highly susceptible to checks and cracks. This condition is conducive to injury by the heat sterilization treatments. Consequently, navel oranges from these two areas were severely injured by the vapor heat treatments. On the other hand, navel oranges from the Riverside and Redlands districts have much tougher peels, and consequently, navels from these two areas withstood the heat treatments much better than fruit from the other two districts.

As mentioned elsewhere in this paper, navel oranges picked very late in the season were more susceptible to injury than good quality navels picked early in the season.

The surface injury on the lemons was not quite as great as on the navel oranges, but the lemons did not store as well as the navels, for internal breakdown in the lemons occurred at ordinary temperatures on the packing floor.

Injuries to Valencia oranges and grapefruit were also influenced by the above-mentioned factors. Both overmature Valencia oranges and grapefruit were injured by the heat treatment processes, but high quality fruit of both of these varieties could withstand the heat treatments without physical injury to the surface of the peel. As far as physical injury to the peel is concerned, the experimental data obtained in this investigation demonstrated that Valencia oranges and grapefruit could successfully withstand the vapor heat treatments better than either the navel orange or lemon varieties. In fruits which were susceptible to injury, the rind collapse and internal breakdown were usually of sufficient magnitude to cause losses to growers by increasing the number of defective fruits and by reducing the storage life of the fruit.

It is worthy of comment, however, that the vapor heat treatments produced off-flavors in the citrus fruits sufficiently intense to be detected by the taste test. Good

Table 3.—Effect of vapor heat treatment (100° F.) on the pH of citrus fruit juices.

VARIETY	pH VALUES OF THE CENTRIFUGED JUICE	
	Controls	Treated
Navels		
1	3.51	3.64
2	3.70	3.82
3	3.60	3.82
4	3.62	3.88
5	3.68	3.83
Grapefruit		
1	3.00	3.14
2	3.11	3.33
3	3.05	3.26
4	3.13	3.30
5	3.06	3.28
Lemons		
1	2.41	2.56
2	2.46	2.63
3	2.32	2.47
4	2.28	2.50
5	2.31	2.48

flavor is indispensable in the sale of any fresh fruit. In the fresh fruit industry the competitive market is so strong that a difference in good flavor is the difference between success and failure of the industry, and any treatment which alters flavor adversely will certainly not enhance the quality of the fresh fruit, and the result will be easily detected by the consuming public.

SUMMARY AND CONCLUSIONS.—The data obtained from these experiments warrant the following conclusions:

Citrus and avocado fruits have been treated by moist heat according to the recommendations authorized by the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine. These recommendations include two methods: (1) the vapor heat "quick run-up" method to 120° F.; and, (2) the vapor heat treatment which requires from 4 to 8 hours to get the fruit up to the required 110° F. temperature.

By this "quick run-up" method the commodity is exposed to saturated vapor at 120° F. and then removed when the internal temperature of 119° F. is reached in the product. This method was applied to navel and Valencia oranges, lemons, grapefruit and avocados.

The severity of injury to citrus fruits depends upon the environment in which the fruit is grown, the degree of maturity and the quality of the fruit. Only the highest quality citrus fruits can withstand the vapor heat treatments without injury.

The avocado fruits tested in these experiments (the Fuerte and Dickinson varieties) could not tolerate the vapor heat treatments.

The navel orange variety was severely injured by the vapor heat treatments, the degree of injury depending upon certain environmental conditions. The peel of the navel orange from some districts is too tender to withstand either the 110° F. or 120° F. temperature treatments. The storage life of navel oranges was significantly reduced by the heat treatments.

Similar experiments on lemons show that the surface injury on the fruits was not quite as great as on the navel orange. The lemons did not store well and could not withstand the ordinary room temperatures on the packing-house floor. The breakdown was so great that the fruit was not acceptable for processing for by-products.

The Valencia orange appears to withstand the heat treatment much better than either navel oranges or lemons; however, Valencia oranges picked late in the season may be severely damaged when given the vapor heat treatment. There is a slight off-flavor in the Valencia orange, but we do not get the marked surface damage to the peel which was obtained in the navel orange.

The grapefruit can withstand the 110° F. treatment very well. Some injury to the peel does occur, but that is markedly influenced by the location in which the fruit is grown. As a generalization, grapefruit and Valencias can withstand the vapor heat treatment much better than navel oranges and lemons.

In all of these experiments, the soluble solids, the pH, the titratable acidity and the ascorbic acid have been determined on the juice of the different varieties of citrus fruits. As a result of the heat treatments, a marked reduction occurred in the titratable acidity and the ascorbic acid of navel and Valencia oranges, grapefruit and lemons. This decrease in free acidity of the treated fruit was accompanied by a corresponding increase in the pH of the juice.

The soluble solids of the treated fruit had a tendency to be slightly lower than that of the control fruit. In most of these experiments, however, the reduction in soluble solids was not statistically significant. In only one series of experiments with lemons was the reduction in soluble solids statistically significant at the 5 per cent level.

The vapor-heat treatments altered the taste of the citrus fruits and produced off-flavors which could be detected by the taste test. The heat treatments destroyed the fresh delicate flavor of the navel orange, and the loss of flavor and the reduction in acidity of the fruit gave the treated navels a flat taste.

The off-flavor in the lemons was considerable. The treated lemon samples which exhibited internal breakdown during subsequent storage developed extremely bad off-flavors.

Off-flavors could be detected in grapefruit and Valencia oranges; however, they did not occur or develop in the storage of these fruits the same degree as they did in the navels and lemons.

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Watch for the Announcement

Systemic Effect of Selected Chemicals on the Bed Bug and Lone Star Tick when Administered to Rabbits[1]

THEODORE R. ADKINS, JR.,[2] WENDELL L. SOWELL,[3] and F. S. ARANT[2]

The control of external parasites of livestock is a very important problem of livestock producers. Within the last 15 years, numerous insecticides suitable for ectoparasite control on animals have been developed. However, their application to animals has been time-consuming and expensive. The advantages of a systemic chemical that can be incorporated in the feed of an animal are readily visualized, provided that the chemical is relatively non-toxic to the animal and toxic to feeding ectoparasites. The problems associated with complete coverage of the animal, loss of insecticide by wear and weathering, machinery for application, and round up of animals would be eliminated.

For many years, entomologists have been interested in the control of ectoparasites of animals by administration of chemicals to the host, but most of the early attempts at control were unsuccessful. Among the first investigators were Parman *et al.* (1928), who studied proprietary products sold as systemics; Bruce (1940), who injected arsenic compounds into a heifer infested with horn flies (*Siphona irritans* (L.)) and screwworms (*Callitroga hominivorax* (Coq.)); Babcock *et al.* (1943), who tried to control lice on goats and calves by feeding sulphur to the hosts; and Creighton *et al.* (1943), who administered sulphur orally to chickens in an attempt to control various species of lice.

Experiments conducted by de Meillon (1946) indicated that the bed bug (*Cimex lectularius* L.), the yellow-fever mosquito (*Aedes aegypti* (L.)) and the tick (*Ornithodoros moubata* (Murray)) either died or showed toxic effects after feeding on rabbits that had been fed the pure gamma isomer of BHC. Garnham (1947) reported that gamma isomer of BHC administered orally to rabbits killed the yellow-fever mosquito feeding on the rabbits.

Various chlorinated hydrocarbons were fed to cattle during tests conducted by Eddy *et al.* (1954). Populations of the stable fly (*Stomoxys calcitrans* (L.)), the horn fly, and the yellow-fever mosquito were reduced when they were allowed to feed upon the cattle receiving lindane. Blood from the cattle that were fed lindane was not toxic to the screwworm *in vitro*. Lindane, dieldrin, aldrin, and chlordane when fed to the cattle showed no toxicity to the common cattle grub, *Hypoderma lineatum* (De Vill.), infesting the animals.

Thirty-three chemicals, administered orally to rabbits by Knipling *et al.* (1948), were tested against the human body louse, *Pediculus humanus humanus* L., and 31 chemicals were tested against the yellow-fever mosquito. The only chemicals that caused complete kill of body lice were some of the indandione compounds; gamma isomer of BHC was the only material that killed all of the yellow-fever mosquitoes. Observations were made on the effects of nine chemicals on the rabbit ear mite, *Psoroptes equi* var. *cuniculi* (Delafond), and of two chemicals on the lone star tick, *Amblyomma americanum* (L.). Gamma isomer of BHC killed the ear mites, but had no effect on the lone star tick.

Lindquist *et al.* (1953) reported that dieldrin, aldrin, and heptachlor, when injected subcutaneously in mice, caused 100 per cent mortality of the deer fly, *Chrysops discalis* Will., feeding on the mice. Dieldrin, aldrin, and lindane killed some but not all of the mosquitoes, *Aedes dorsalis* (Meig.), taking blood meals. DDT, TDE, methoxychlor, toxaphene, Perthane, the fluoro and butyl analogs of DDT, and a group of sulfone compounds were ineffective against both test insects. Aldrin, dieldrin, allethrin, and heptachlor injected in cattle gave poor kills of the horse flies, *Tabanus sonomensis* O. S., *T. productus* Hine, and *T. punctifer* O. S.; the deer flies, *C. discalis* Will. and *C. bishoppi* Bren.; and the mosquitoes, *A. dorsalis* (Meig.) and *A. flavescens* (Müller).

In preliminary experiments, McGregor *et al.* (1954) found that Diazinon administered by injection to cattle and Diazinon and Bayer L 13/59 given orally resulted in excellent kill of cattle grubs, *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.). Chlorthion was less effective and Bayer 21/199 was ineffective.

MATERIALS AND METHODS.—Thirteen chemicals were tested to determine their toxicities to the domestic rabbit and to certain bloodsucking ectoparasites feeding on the rabbit. The materials used in the experiments were: schradan in aqueous solution; Diazinon in the technical form; Bayer 21/116, 0-[2-(ethyl mercapto)ethyl]-0, 0-dimethyl thiophosphate, in an emulsion; Bayer 21/199 in acetone solution; Bayer 18/178, 0-[2-(ethyl mercapto) methyl]-0,0-dimethyl thiophosphate, in an emulsion; Bayer L 13/59 in aqueous solution; chlorthion in an emulsion; malathion in the technical form; isooctyl thioglycolate in the technical form; phenethyl butyrate in the technical form; phenethyl alcohol in the technical form; hexamethylphosphoramide in the technical form; and Ladner's Parasite and Insect Exterminator, a mixture of epsom salts, copperas, sulphur, hydrated lime, spirits of turpentine and nicotine, without dilution.

Procedure with Rabbits.—Chemicals were administered through a stomach tube to the domestic rabbit to determine the highest approximate dosage that could be given without causing severe toxic symptoms. Little was known about the toxicities of the compounds and a starting dose was arbitrarily selected. If the first dose killed the rabbit, successively lower doses were given until one failed to kill. Conversely, if the first dose caused no visible symptoms, successively larger ones were administered until an animal was killed. A different rabbit was used each time. Since there were no replications of treatments,

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[2] Agricultural Experiment Station of the Alabama Polytechnic Institute, Auburn.
[3] Alabama State Department of Toxicology and Criminal Investigation, Auburn.

Table 1.—Results of toxicity experiments with rabbits that received oral doses of various insecticides.

Insecticides	Dose to Rabbits (mg./kg.)			
	No. of Rabbits	Highest Sublethal	Lowest Lethal	For Arthropod Tests
Ladner's Mixture	10	8,800	9,000	8,800
Hexamethylphosphoramide	7	1,300	1,500	1,300
Phenethyl alcohol	8	1,000	2,000	1,000
Phenethyl butyrate	6	1,000	2,000	1,000
Iso-octyl thioglycolate	7	1,000	1,200	1,000
Malathion	10	900	1,000	800
Chlorthion	10	375	450	375
Bayer L 13/59	10	200	285	200
Bayer 18/178	14	130	135	130
Bayer 21/199	12	100	150	100
Bayer 21/116	12	125	150	95
Diazinon	12	25	50	20
Schradan	8	25	27.5	20

the results were considered preliminary. If the highest dose that failed to kill the rabbit had no systemic value against the test arthropods, the chemical was eliminated from further testing.

Procedures with Test Arthropods.—In conducting experiments with arthropods, nymphs of the lone star tick and the fifth instar of the bed bug were placed on treated rabbits to feed. Different rabbits were used for bed bugs and ticks to decrease injury to the rabbits from handling.

One hour after the rabbit received a dose of the chemical, 30 bed bug nymphs were allowed to feed on each rabbit. Counts of dead and live bugs were made 24 hours after they fed and again 6 days later, after the living bugs had molted. From five to 45 nymphs of the lone star tick were allowed to attach to each rabbit. The rabbits were dosed 2 days after the ticks were attached. Four to 5 days after attaching, or 2 to 3 days after the rabbits were dosed, the living engorged ticks dropped. Some ticks did not engorge and drop but died attached to the rabbit. Initial mortality counts of all lots were made when all the ticks dropped from the untreated check. Final mortality counts were made when all the ticks in the check molted. The bed bugs and ticks were kept in molting chambers in a constant temperature box maintained at 80° F.

Results.—Results of the toxicity experiments on rabbits are presented in table 1. Ladner's Parasite and Insect Exterminator was the least toxic to the rabbit of the materials tested, and schradan was the most toxic. Minimum doses which were fatal to the rabbit ranged from 27.5 milligrams of schradan per kilogram of rabbit to 9,000 milligrams of Ladner's mixture per kilogram of rabbit.

Data on the mortality of bed bugs are presented in table 2. Several chemicals administered to rabbits exhibited systemic action. The following materials at the indicated dosages gave 100 per cent kill of the bed bugs: Bayer L 13/59, 200 mg./kg.; Bayer 18/178, 130 mg./kg.; Bayer 21/116, 95 mg./kg.; schradan, 20 mg./kg. Although bed bugs did not feed to repletion on animals treated with hexamethylphosphoramide, 63 per cent of the test insects died. This chemical should receive further study. The other compounds tested had little or no effect. No mortality occurred among the bed bugs which fed on untreated rabbits.

Data on the mortality of the ticks are presented in table 3. All the ticks died while still attached to the rabbits that had received Bayer L 13/59, Bayer 21/116, and Bayer 18/178. The ticks that fed on rabbits receiving hexamethylphosphoramide engorged and dropped normally; however, 100 per cent mortality occurred at molting time. The other compounds tested had little or no effect on the ticks. No mortality occurred in the lots of ticks that fed on the untreated rabbits.

Summary.—Preliminary experiments were conducted to determine the effects of 13 chemicals administered orally to the domestic rabbit on the rabbit and on fifth instar bed bugs, *Cimex lectularius* L., and nymphs of the lone star tick, *Amblyomma americanum* (L.), feeding on the rabbits. Bayer L 13/59, Bayer 18/178 (0-[2-(ethyl mercapto) methyl]-0,0-dimethyl thiophosphate), and Bayer 21/116 (0-[2-(ethyl mercapto)ethyl]-0,0-dimethyl thiophosphate) caused 100 per cent mortality to bed bugs and ticks feeding on treated rabbits. Hexamethylphosphoramide caused 63 per cent mortality of bed bugs and 100 per cent mortality of ticks. Schradan had no effect on ticks, but killed 100 per cent of the bed bugs feeding on the dosed rabbits. These insecticides showed no severe toxic symptoms to the rabbits at rates used for arthropod tests. The insecticides and rates were: Bayer L 13/59, 200 mg./kg.; Bayer 18/178, 130 mg./kg.; Bayer 21/116, 95 mg./kg.; hexamethylphosphoramide, 1,300 mg./kg.; and schradan, 20 mg./kg. Eight chemicals failed to kill

Table 2.—Mortality of fifth-instar bed bugs that fed on rabbits dosed orally with insecticides.

Insecticide	Dose to Rabbit mg./kg.	Per Cent Bed Bug Mortality After Feeding	
		24 Hours	6 Days
Check	0	0	0
Bayer L 13/59	200	100	—
Bayer 18/178	130	100	—
Bayer 21/116	95	100	—
Schradan	20	100	—
Diazinon	20	33.3	36.6
Hexamethylphosphoramide	1,300	10	63.3
Ladner's Mixture	8,800	3.3	10
Iso-octyl thioglycolate	1,000	0	0
Phenethyl alcohol	1,000	0	0
Phenethyl butyrate	1,000	0	6.7
Malathion	800	0	10
Chlorthion	375	0	13.3
Bayer 21/199	100	0	0

Table 3.—Mortality of lone star ticks attached to rabbits subsequently dosed orally with insecticides.

Insecticides	Dose to Rabbit (mg./kg.)	No. Attached to Rabbit	Per Cent Mortality of Ticks	
			Attached to Host	At Molting Time
Check	0	45	0	0
Bayer L 13/59	200	10	100	—
Bayer 18/178	130	5	100	—
Bayer 21/116	95	10	100	—
Schradan	20	10	0	0
Diazinon	20	5	0	0
Hexamethylphosphoramide	1,300	5	0	100
Ladner's Mixture	8,800	5	0	0
Iso-octyl thioglycolate	1,000	5	0	0
Phenethyl alcohol	1,000	5	0	0
Phenethyl butyrate	1,000	5	0	0
Malathion	800	5	0	0
Chlorthion	375	5	0	20
Bayer 21/199	100	5	0	0

all of the test arthropods at doses causing no severe toxic symptoms to rabbits.

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Lice Control on Chickens with Chlorinated Hydrocarbon Insecticides[1]

H. E. FAIRCHILD and PAUL A. DAHM,[2] *Kansas Agricultural Experiment Station, Manhattan*

Chickens in the United States may be infested with one or more of seven species of Mallophaga (Benbrook 1945, Fairchild & Dahm 1954). Whether chickens lose weight and produce fewer eggs as the result of lice infestations is a controversial subject among poultrymen. Mohler *et al.* (1942) placed the loss resulting from external parasites of poultry, including lice, at $85 million per year. Van Es & Olney (1941) and Edgar & King (1950) also reported detrimental effects from chicken lice. However, Warren *et al.* (1949) did not find a significant difference in egg production between lice-infested and lice-free laying hens. To poultrymen who work with infested flocks, lice are unquestionably a source of irritation and unpleasantness.

The use of organic insecticides to control ectoparasites on animals, including lice on chickens, has created the problem of evaluating not only their toxicity to animals but also the possible hazards to humans of insecticidal residues in the tissues and food products of treated animals. Although several of the newer insecticides, especially lindane and dieldrin, had shown promise for control of poultry ectoparasites when this study was initiated, additional information was needed on the accumulation of these insecticides or their metabolites in tissues of chickens. Furthermore, it was not known whether dieldrin dusts might have a toxic effect when applied to chickens. Thus with the advent of these and several other new insecticides there was a need to investigate both these materials and various other methods of chicken lice eradication which might be more rapid and economical than the classical "pinch method" with sodium fluoride described by Bishopp & Wood (1939).

Previous reports dealing with the newer insecticides used or considered for control of chicken lice include the Poultry Council of the State College of Washington (1947), Edgar *et al.* (1949), Furman & Bankowski (1949), Rosenberg & Adler (1950), Rosenberg & Tanaka (1950), Eden (1951), Quigley (1951), Arant (1952), Turner & Eden (1952), Anderson *et al.* (1952), and Sherman & Rosenberg (1953).

Five principal experiments are reported in this paper. They are described below. For convenience, the sequence in which they are presented here will be used throughout this paper.

EXPERIMENT I.—A comparison of the toxicity to chickens and tissue residues of 1.0, 0.25, and 0.0625% dusts of dieldrin with that of the same concentrations of lindane applied to chickens by the "pinch method."

EXPERIMENT II.—A preliminary evaluation of the efficacy of a 1.5% aldrin dust scattered over the litter of the poultry house for louse control.

EXPERIMENT III.—A comparison of chicken lice control obtained by one application of a 1% dieldrin dust with that obtained with a 1% lindane dust, each applied with a rotary duster over roosting chickens.

EXPERIMENT IV.—A comparison of chicken lice control obtained by one application with a rotary duster of

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[2] Present address: Grasselli Chemicals Department, E. I. du Pont de Nemours & Co., Experiment Station, Wilmington, Del. and Dept. of Zoology and Entomology, Iowa State College, Ames, respectively.

1.5% aldrin, 5.0% chlordane, 1.5% heptachlor, and 1.0% lindane dusts to roosting chickens.

EXPERIMENT V.—A comparison of chicken lice control obtained by dusting the litter of poultry houses a single time with 1.5% aldrin, 5.0% chlordane, and 1.0% lindane dusts.

MATERIALS AND METHODS.—*Insecticides.*—The five insecticides used in these experiments were aldrin, chlordane, dieldrin, heptachlor, and lindane. Aldrin was used as a 1.5% dust[3] in Experiments II, IV, and V. Chlordane was used as a 5.0% dust[4] in Experiments IV and V. Dieldrin was used as a 1.0% dust[5] in Experiments I and III; this dust was diluted also with pyrophyllite to form dusts containing 0.25% and 0.0625% dieldrin for use in Experiment I. Heptachlor was used as a 1.5% dust[4] in Experiment IV. Lindane was used as 1.0%, 0.25%, and 0.0625% dusts in Experiment I[6] and as a 1.0% dust in Experiments III, IV, and V.[6]

Chickens and Poultry Houses.—All chickens used in these studies were maintained on the Kansas State College Poultry Farm. The 115 laying hens used in Experiment I were New Hampshires with the exception of three Rhode Island Reds. In Experiment II, 25 White Rock roosters, approximately 7 months old, were used. These birds were being used by the College Poultry Husbandry Department to study the environmental influence of the utilization of diethyl stilbesterol. A total of 1970 laying hens with infestations of lice were used in Experiments III, IV, and V. The 366 hens used in Experiment III were mostly White Rocks with a few New Hampshires, Rhode Island Reds, and crossed breeds. The 712 hens used in Experiment IV consisted of White Rocks, New Hampshires, and Rhode Island Reds. The 892 hens used in Experiment V consisted of White Leghorns, White Rocks, New Hampshires, and Rhode Island Reds. The breeds of chickens used in each experiment are listed in detail under the tabular presentation of results.

Because it is possible that differences in results might occur under various conditions of housing and husbandry, the conditions under which these experiments were conducted are described in some detail. All chickens used in Experiment I were maintained in sections of a Kansas straw-loft poultry house (Wendling & Seaton 1949). The roosters used in Experiment II were penned in a multi-unit type brooder house with an old built-up corn cob litter. The hens used in Experiment III were kept in shed-roof type houses with one exception which was the Kansas straw-loft type. The windows of the poultry houses were left open for the duration of this experiment. The hens used in Experiment IV were kept in either shed-roof or Kansas straw-loft type houses. The windows of these houses were adjusted in the evening according to the following plan during the period of Experiment IV (Nov. 22, to Dec. 12, 1951): all windows were left open at temperatures of 35° F. or above; from 25° to 35° F. all but one window of each section of the house were closed; all windows were closed below 25° F. In the morning, all window curtains were open at temperatures of 30° F. or above; below 20° F. all curtains were kept closed until late morning and then, if the sun were shining, one or two curtains were dropped in each section. The hens used in Experiment V were kept in Kansas straw-loft type houses; one group was maintained in a new Kansas straw-loft laying house for large flocks (Seaton *et al.* 1949). These houses were provided with either built-up cob or straw litters. The management of windows in these houses was similar to that described for Experiment IV.

Infestations of Chicken Lice.—The three species of lice occurring as natural infestations on the chickens used in Experiments III, IV, and V were: the chicken body louse, *Eomenacanthus stramineus* (Nitz.); the fluff louse, *Goniocotes gallinae* (Deg.) and the shaft louse, *Menopon gallinae* (L.). Although each of these species was present in the three experiments, there were differences in prevalence which will be noted under "Results."

The pre-treatment estimates of infestations of lice on the chickens in each house used in Experiment III were made 4 to 7 days before application of the two insecticides. The procedure used was to part the feathers and count or estimate the lice on all areas of the body for 10 hens selected at random. The other birds in each house were examined briefly to confirm the presence of lice. Post-treatment examinations of the hens were made in the same way as the pre-treatment examinations.

The pre-treatment estimates of lice infestations for Experiment IV, made 1 to 4 days before application of the insecticides, and Experiment V, made 6 to 9 days before application of the insecticides, were made in the same general manner as outlined for Experiment III above. The post-treatment examinations were made in the same way as the pre-treatment examinations except that in Experiments IV and V a total of 20 chickens were examined in each house in an effort to compensate for those few birds found to be without lice in the pre-treatment examinations.

Methods of Insecticide Application.—In Experiment I the "pinch method," recommended by Bishopp & Wood (1939) for dusting poultry with sodium fluoride, was adopted for applying the dieldrin and lindane dusts. Ten grams of dust were applied to each bird; a rather thorough distribution of the dust over each bird was assured by the systematic application sequence of the pinch method.

The 1.5% aldrin dust used in Experiment II was scattered by hand onto the corn cob litter of the poultry house at the rate of 2.5 pounds of dust per 100 square feet of floor area. This dust was applied October 29, 1951. The roosters in this house had free access to the treated litter for the 39-day period between application of the dust and time of sacrifice of the birds.

In Experiment III a single application of the 1.0% dieldrin and lindane dusts was made using a rotary duster.[7] The dusts were applied at approximately 15 grams of dust per bird onto chickens that had just gone to roost. In applying the dusts, the fishtail-shaped nozzle of the duster was held as close to the individual birds as pos-

[3] Samples 8258 (Experiments II, IV, and V) and 8620 (Experiment V), supplied by Julius Hyman & Co. (now Shell Chemical Corp.), Denver, Colo.
[4] Nov. 18, 1951 sample from Velsicol Corp., Chicago, Ill.
[5] Sample 6164, supplied by Julius Hyman & Co. (now Shell Chemical Corp.), Denver, Colo.
[6] The dust dilutions used in Experiment I were prepared by diluting a Nov. 9, 1950 sample of "Isotox" Wettable No. 250 with pyrophyllite; the 1.0% lindane dusts used in Experiments III, IV, and V were "Isotox" No. 10 dust samples received on July 23, 1951, August 24, 1951, and January 2, 1952 respectively for the three experiments. All lindane samples were supplied by California Spray-Chemical Corp., Richmond, Cal.
[7] Dobbins No. 200 Duster, manufactured by the Dobbins Manufacturing Co., Elkhart, Ind.

sible. An additional small quantity of dust was applied also to the nests and dropping boards of each house with the rotary duster. The dusts used in Experiment IV were applied in the same manner and at the same rate as those used in Experiment III.

The dusts used in Experiment V were scattered by hand onto the litter of each poultry house at a rate of 2 pounds of dust per 100 square feet of floor area.

Insecticidal Residue Determinations.—The hens used in Experiment I were sacrificed at intervals to obtain samples of fat, liver, and skin tissues for insecticidal residue determination. For the most part, the following schedule was used. Twelve treated birds were selected randomly and sacrificed at intervals of 1, 2, 3, 4, 5, and 8 weeks after dusting. Two hens were taken from each of the groups treated with one of the three dust concentrations of dieldrin and lindane. Two hens from the untreated group were sacrificed also according to the above schedule. Thus, the combined sacrifice for the six intervals was 84 birds. In addition, seven hens were sacrificed 12 weeks after dusting.

Each tissue sample was weighed and wrapped immediately in either aluminum foil or self-sealing waxed paper. All samples were retained in a frozen condition and subsequently shipped in dry ice (solid carbon dioxide) to separate laboratories for analysis. The presence of dieldrin or lindane in the tissue samples was tested by employing the bioassay methods of either Sun & Sun (1952) for dieldrin or Hoskins & Messenger (1950) for lindane. Both methods employ the house fly, *Musca domestica* L., as the test insect.

RESULTS.—*Experiment I.*—Although the birds were observed daily during the 12-week period of this experiment for any toxic effects which might be due to the insecticides, no symptoms ever developed. Seven of the hens died during the experiment; pathological reports for these birds attributed the cause of death in all cases except one to round worms or trichomoniasis.[8] The death rate of these birds was about normal at that time for the Poultry Farm flocks.

The weight changes of the 84 birds sacrificed during the first 8 weeks of this experiment were analyzed statistically to determine whether the insecticides might have had any adverse effects, which would have been manifest in this manner, upon the birds. The analysis of variance indicated that neither insecticide had any detrimental effect upon weight changes.

Table 1.—**Dieldrin residues in fat from chickens dusted[a] with 10 grams of various dieldrin dusts by the "pinch method."**

PER CENT ACTIVE INGREDIENT	DIELDRIN RESIDUES (p.p.m.)[b,c]			
	Sacrifice Interval—Weeks After Dusting			
	1	2	8	12
0.0625	0.7	0	1.6	—
0.25	1.9	0.9	—	3.0
1.0	0.8	0.5	—	1.0

[a] Dusts applied Jan. 12, 1951.
[b] Analyses done by Julius Hyman & Co. (now Shell Chemical Corp.), Denver, Colo.
[c] Pooled tissues from two birds were used for each datum of the 1- and 2-week intervals; tissues from single birds were used for each datum of the 8- and 12-week intervals.

Although tissue samples of fat, liver, and skin from the dieldrin-treated birds were submitted for analysis, only data for the fat samples were received. These are summarized in table 1. Although additional fat samples were supplied the analytical laboratory for analysis, it was reported that the continuing persistence of dieldrin residues in the fat samples permitted a reduced number of analyses to be made.

Residues of lindane in fat and liver samples taken from the chickens dusted with this insecticide dissipated rapidly as shown in Figures 1 & 2. Lindane residues in skin samples taken from birds 2 weeks after dusting were reported to be 0.44, 0.84, and 7.5 p.p.m., respectively, for the 0.0625, 0.25, and 1.0% lindane dust treatments.

Experiment II.—The roosters used in this experiment were infested lightly with the three species of lice mentioned above. Application of a 1.5% aldrin dust to the corn cob litter was followed by an examination of the roosters 8 days later. No lice could be found. These results were encouraging and prompted further investigations (see Experiment V).

Experiment III.—It was found that the laying hens used in this experiment were infested mostly with the

[8] Reported by Dr. L. E. Erwin, Department of Bacteriology, Kansas State College.

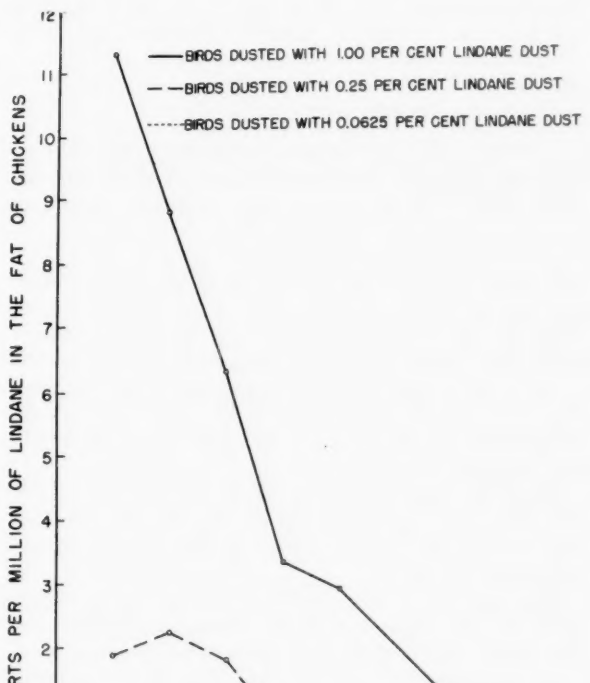

FIG. 1.—Dissipation of lindane residues in fat from chickens dusted with 10 grams per bird with three lindane dusts by the "pinch method." Each datum represents a pooled sample from two chickens.

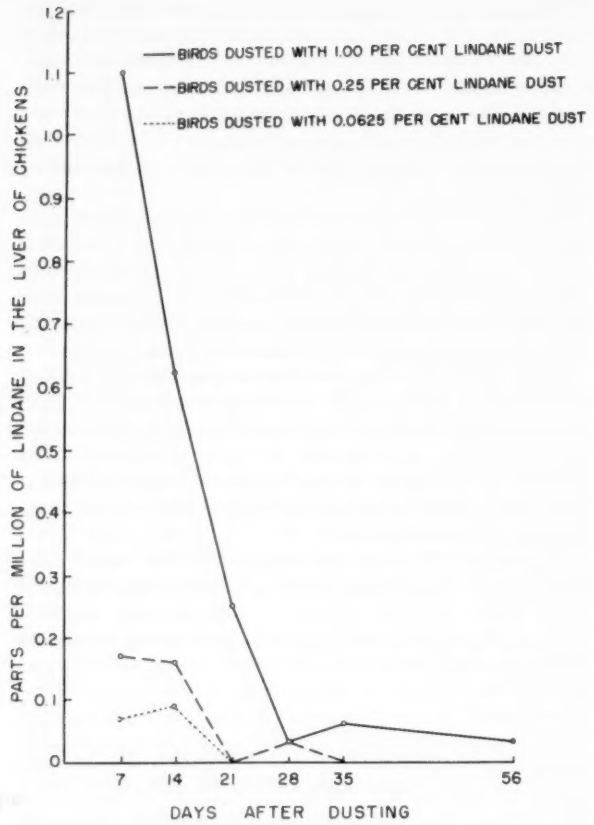

FIG. 2.—Dissipation of lindane residues in livers from chickens dusted with 10 grams per bird with three lindane dusts by the "pinch method." Each datum represents a pooled sample from two chickens.

shaft louse; the fluff louse was next in abundance, while only an occasional chicken body louse was observed. While examining all the hens in the four houses of mixed breeds (see Table 2) before dusting, it was observed that birds of the red-feathered breeds, mainly New Hampshires, had a much lower infestation of lice than birds of the white-feathered breeds. Also, the four houses of White Rocks appeared most heavily infested with lice.

About 20 minutes were required to apply the dust in each of the poultry houses. The lice control data obtained with dieldrin and lindane dusts in this experiment are summarized in table 2.

Experiment IV.—The chickens used in this experiment were infested primarily with the chicken body louse; the shaft louse was next in abundance, while only an occasional fluff louse was observed. Not more than 15 minutes were required to apply the dust in each of the poultry houses. The lice control data obtained with aldrin, chlordane, heptachlor, and lindane dusts in this experiment are summarized in table 3. It is interesting that all four of the insecticidal dusts eliminated all lice within 48 hours after application.

Experiment V.—The chickens used in this experiment were infested with the same three species of lice and order of prevalence as reported above in Experiment IV. The hand-scattering of the insecticidal dusts onto the litter of each poultry house could be accomplished in about 15 minutes. The lice control data obtained with aldrin, chlordane, and lindane dusts in this experiment are summarized in table 4. Each of these dusts essentially eliminated the lice within 48 hours after application; moreover, the chickens remained free of lice during the 60-day duration of the experiment.

Table 2.—Chicken lice control obtained by one application with a rotary duster of dieldrin or lindane dusts to roosting chickens.

Dusts[a]	Breed of Chickens	Hens per House	Estimated Pretreatment Infestation per Hen[b]	Estimated % Reduction on Date Indicated After Dusting[b] 2nd	10th
Dieldrin, 1%	White Rock	47	200	90	99
	White Rock	35	400	85	85
	Mixed[c]	48	200	90	90
	Mixed[c]	58	150	100	99
Total or Average		188	238	91	93
Lindane, 1%	White Rock	51	200	100	99[d]
	White Rock	32	400	100	100
	Mixed[c]	46	250	100	100
	Mixed[c]	49	175	100	100
Total or Average		178	256	100	100

[a] Dusts applied August 6 and 7, 1951, at the rate of approximately 15 grams per bird. The average maximum and minimum temperature during this experiment were 88° and 64° F., respectively.
[b] The estimated pre-treatment infestation based upon a careful examination of 10 birds in each house. All other birds were examined briefly and the presence of lice confirmed. Louse infestation estimated in a similar manner for each post-treatment interval.
[c] Principally White Rocks plus a few New Hampshires, Rhode Island Reds, or cross breeds.
[d] One live shaft louse noted.

SUMMARY.—Several experiments were performed to determine the effectiveness of five insecticides, aldrin, chlordane, dieldrin, heptachlor, and lindane, for chicken lice control. Dust formulations of these insecticides were applied to chickens in several ways. Toxicity and tissue

Table 3.—Chicken lice control obtained by one application with a rotary duster of several insecticides to roosting chickens.

Dusts[a]	Breeds of Chickens	Hens per House	Estimated Pretreatment Infestation per Hen[b]	Estimated % Reduction on Date Indicated After Dusting[c] 2nd	10th	21st
Aldrin, 1.5%	Mixed[d]	97	150	100	100	100
	Mixed[d]	114	125	100	100	100
Total or Average		211	138	100	100	100
Chlordane, 5.0%	White Rock	89	75	100	100	100
	White Rock	104	125	100	100	100
Total or Average		193	100	100	100	100
Heptachlor, 1.5%	Mixed[d]	79	125	100	100	—[e]
	Mixed[d]	80	125	100	100	—[e]
Total or Average		159	125	100	100	
Lindane, 1.0%	Mixed[d]	55	75	100	100	100
	Mixed[d]	94	100	100	100	100
Total or Average		149	88	100	100	100

[a] Dusts applied Nov. 21 & 22, 1951, at the rate of approximately 15 grams per bird. Average maximum and minimum temperatures during this experiment were 51° and 28° F., respectively.
[b] An estimated infestation based upon a careful examination of 10 birds in each house 1 to 4 days before application of the insecticides. All other birds were examined briefly and the presence of lice confirmed on all but a few birds.
[c] Based upon a careful examination of at least 20 birds in each house.
[d] Principally White Rocks and New Hampshires or Rhode Island Reds.
[e] These birds were not available for examination.

Table 4.—Chicken lice control obtained by a single application of several insecticides to the litter of the poultry houses.

Dusts[a]	Breed of Chickens	Hens per House	Estimated Pretreatment Infestation per Hen[b]	Estimated % Reduction on Date Indicated After Dusting[c]			
				2nd	10th	24th	60th
Aldrin, 1.5%	White Rock	141	125	100	100	100	—[f]
	Leghorn	78	175	100	100	100	100
	Leghorn	84	175	100	100	100	100
Total or Average		303	158	100	100	100	100
Chlordane, 5%	White Rock	123	125	99	100	100	—[f]
	Mixed[d]	106	75	99	100	100	100
	Leghorn[e]	57	50	99	100	100	100
Total or Average		286	83	99	100	100	100
Lindane, 1%	White Rock	135	100	100	100	100	—[f]
	White Rock	78	100	100	100	100	100
	White Rock	90	100	100	100	100	100
Total or Average		303	100	100	100	100	100

[a] Dusts applied during the period February 4 to 6, 1952, at the rate of 2 pounds per 100 square feet of floor area. The average monthly maximum and minimum temperatures during this experiment were 50° and 26° F., respectively.

[b] An estimated infestation based upon a careful examination of ten birds in each house six to nine days before applicaton of the insecticides. All other birds were examined briefly and the presence of lice confirmed on all but a few birds.

[c] Based upon a careful examination of at least 20 birds in each house at each post-treatment interval.

[d] Principally White Rocks, and New Hampshires or Rhode Island Reds.

[e] Birds in this house were on a carotenoid-free diet but were receiving adequate Vitamin A.

[f] These birds were not available for examination.

residue studies were made of two of these insecticides, dieldrin and lindane. Three species of lice occurred as natural infestations on the chickens used in these experiments: the chicken body house, *Eomenacanthus stramineus* (Nitz.); the fluff louse, *Goniocotes gallinae* (Deg.); and the shaft louse, *Menopon gallinae* (L.).

Rapid, economical, and effective chicken lice control was obtained by applying insecticidal dusts either with a rotary duster onto chickens which had gone to roost or by hand-scattering the dusts over the poultry house litter.

Lice control was obtained by one application with a rotary duster of 1.5% aldrin, 5.0% chlordane, 1.0% dieldrin, 1.5% heptachlor, and 1.0% lindane dusts. All dusts were applied over the roosting chickens at a rate of approximately 15 grams of dust per bird. Most or all of the lice originally present on the chickens were killed within 48 hours after application of the dusts. The chickens remained essentially free of lice in all cases, except dieldrin, for the duration of the experimental periods of 10 and 21 days. In all probability, freedom from lice would continue much longer than these intervals.

Lice control was obtained also by simply scattering by hand 1.5% aldrin, 5.0% chlordane, and 1.0% lindane dusts a single time onto the litter of poultry houses at the rate of approximately 2 pounds of dust per 100 square feet of floor area. All of the lice originally present on the chickens were killed within 48 hours after application of the aldrin and lindane dusts; the chickens remained free of lice for 60 days, the length of the experiment. It is likely that under these conditions, chickens would remain free of lice for a much longer period of time.

A comparison was made of the toxicity to chickens of 1.0, 0.25, and 0.0625% dieldrin and lindane dusts applied by the "pinch method" at the rate of 10 grams of dust per bird. No toxic effects from either of these insecticides were observed during the 12-week experimental period. Nor did either insecticide have any detrimental effect upon weight changes in the birds during the first 8 weeks of the experiment (duration of this phase). Lindane residues from successive fat and liver samples dissipated rapidly. Residue values reported for a limited number of skin samples taken 2 weeks after dusting from the lindane-treated birds were 0.44, 0.84, and 7.5 p.p.m., respectively, for the 0.0625, 0.25, and 1% lindane dust treatments. Dieldrin residues reported in fat samples from two chickens dusted 12 weeks previously with 10 grams of either 1.0 or 0.25% dieldrin dusts by the "pinch method" were 1 and 3 p.p.m., respectively.

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Effectiveness of Dilan and Certain Candidate Synergists Against DDT-Resistant House Flies[1,2]

THEODORE L. HOPKINS and ROBERT A. HOFFMAN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

In recent years investigators have screened numerous compounds seeking materials that would increase the effectiveness of DDT and other chlorinated hydrocarbon insecticides against various species of insects. Perry & Hoskins (1950, 1951) have shown piperonyl cyclonene to increase the toxicity of DDT to resistant house flies, *Musca domestica* L. March & Metcalf (1950) tested DDT with a number of pyrethrum synergists such as piperonyl butoxide, N-isobutylundecylenamide (IN-930), and sesamin, but found no indication of increased effectiveness.

In the course of screening chemicals as synergists with organic phosphorous compounds at the Corvallis, Ore., laboratory, a number of materials were found to increase the effectiveness of Dilan against DDT-resistant house flies. Compounds demonstrating the greatest activity with Dilan were pyrethrum synergists or materials chemically similar to them. Additional laboratory tests have therefore been conducted with these combinations as residual treatments on glass and wood surfaces and by topical methods. Three- to five-day-old house flies (*Musca*

[1] Most of the compounds tested were synthetized by W. F. Barthel and S. I. Gertler.

[2] Accepted for publication November 4, 1954.

Table 1.—Effectiveness of certain compounds for increasing the initial and residual toxicity of Dilan to DDT-resistant house flies.[a]

Candidate Synergist	Per Cent Mortality After Exposure on Indicated Day After Treatment					
	Initial	7th	14th	21st	28th	42nd
Acetic acid, phenyl-alpha-allylpiperonyl ester	100	98	84	68	50	—
Acetic acid, alpha-butylpiperonyl ester	100	97	—	87	66	44
Benzoic acid, alpha-allylpiperonyl ester	13	0	—	—	—	—
Bicycloheptenedicarboximide, N-(2-ethylhexyl)-	90	89	53	64	62	56
Chlorinated terphenyl (Aroclor 5460)	0	0	—	—	—	—
Chrysanthemumic acid, alpha-allylpiperonyl ester	94	92	47	53	39	—
Chrysanthemumic acid, alpha-butylpiperonyl ester	87	54	24	—	—	—
Chrysanthemumic acid, alpha-ethylpiperonyl ester	100	73	41	—	—	—
Chrysanthemumic acid, alpha-(2-methylallyl) piperonyl ester	63	47	27	—	—	—
Chrysanthemumic acid, alpha-propylpiperonyl ester	97	94	72	68	61	—
m-Dioxane, 5-butyl-5-ethyl-2-(3,4-methylenedioxyphenyl)	93	73	60	54	—	—
m-Dioxane, 4,6-dimethyl-2-(3,4-methylene-dioxyphenyl)	97	3	—	—	—	—
1,3-Dioxolane, 2-(3,4-methylenedioxyphenyl)-4,5-dimethyl	94	56	0	—	—	—
1,3-Dioxolane, 2-(3,4-methylenedioxyphenyl)-4-methyl	100	90	—	41	—	—
Fencholic acid, alpha-allylpiperonyl ester	83	0	—	—	—	—
Formic acid, alpha-(3-phenylpropyl) piperonyl ester	100	90	100	86	79	80
Phthalic acid, hexahydro-, dibutyl ester	100	91	81	72	84	40
Phthalic acid, methylcyclohexyl ester	70	57	37	—	—	—
Piperonyl butoxide	100	100	88	96	100	94
Propionic acid, alpha-cyclohexylpiperonyl ester	100	94	100	98	52	9
Propionic acid, alpha-propylpiperonyl ester	100	100	100	100	90	97
Senecioic acid, alpha-allylpiperonyl ester	97	100	95	100	100	98
Sesamin, concentrate	100	80	70	46	—	—
Succinic acid, N,N-diamyl-, propyl ester	100	—	70	68	80	64
Succinic acid, N,N-dipropyl-, ethyl ester	100	94	—	67	12	—
Succinamic acid, N,-diisopropyl-, ethyl ester	99	70	67	82	69	17
Sulfoxide	100	98	81	83	71	45
Thiocyanic acid, 2-(2-butoxyethoxy)-ethyl ester, 80% (Lethane 384)	96	97	46	0	—	—
Undecenamide, N-isobutyl-	100	—	82	82	68	44
Velsicol AR-60 (chiefly di- and tri-methyl naphthalenes)	22	0	—	—	—	—

[a] Average of 2 to 4 tests.

domestica L.) of the DDT-resistant Orlando No. 1 strain were used in most tests. A single test series was run with the stable fly (*Stomoxys calcitrans* (L.)).

Acetone solutions of the combination were applied to the inside of quart glass jars, and 2 hours later 20 to 25 female flies were exposed in them for 10 minutes and then removed to clean containers, and the mortality determined after 24 hours. The treated jars were held at room temperature and retested at weekly intervals for persistence. A total of 30 candidate synergists in combination with Dilan were tested by this method at a dosage of 25:5 mg./sq. ft. Several of the materials gave a high initial mortality with Dilan, and three of them were outstanding for residual effectiveness (Table 1). Piperonyl butoxide, the alpha-propylpiperonyl ester of propionic acid, and the alpha-allylpiperonyl ester of senecioic acid caused 94, 97, and 98 per cent mortality, respectively, at 42 days. Velsicol AR-60 and the chlorinated terphenyl were almost completely ineffective. Dilan and the candidate synergists when tested separately caused no mortality to flies at the dosages used. These three promising synergists with Dilan were then applied to the glass jars at various rates but in the same ratio of toxicant to synergist. House flies or stable flies were used in these tests.

At the low dosage of 12.5 mg./sq. ft. of synergist plus 2.5 mg./sq. ft. of Dilan (Table 2) mortalities of 84 to 98 per cent of resistant house flies were recorded. Dilan alone at 400 mg./sq. ft. failed to kill any flies exposed to the residue for 10 minutes. Stable flies were more susceptible than house flies. Dilan alone at 200 mg./sq. ft. caused 35 per cent mortality. Residues of 5 and 1 mg./sq. ft. of synergist and toxicant, respectively, gave 70 to 95 per cent mortality.

For a more practical test the same three combinations in acetone solutions were sprayed on unpainted plywood panels at the rate of 250 mg. of synergist to 50 mg. of toxicant per square foot. Twenty-five female house flies under Petri dishes were exposed on these panels for 2, 4, or 24 hours. All three of these synergists increased the toxicity of Dilan (Table 3), but the increase was not so great as that obtained on glass (Table 2).

Separation of the chemicals with reference to time of application is often done as a test of synergism. Therefore, in one series of tests female house flies were treated topically with 1 cu. mm. of an acetone solution of piperonyl butoxide and 5 minutes to 24 hours later with Dilan. Application rates were 5 micrograms of synergist and 1 microgram of toxicant per fly. The flies were then held for 24-hour mortality readings. The results of these tests, tabulated below, demonstrate that the effectiveness of Dilan was increased by the addition of piperonyl butoxide in both separate and combined treatments. Here again, however, the increase was not nearly so great as when the materials were tested as residues on glass.

Treatment	*Per cent mortality*
Piperonyl butoxide followed by Dilan after—	
5 minutes	96
30 minutes	92
4 hours	88
24 hours	84
Dilan plus piperonyl butoxide	81
Dilan alone	55
Piperonyl butoxide alone	0

The data also indicate that as the time interval between the applications increased the effect of the synergist became less marked. Furthermore, Dilan alone was more toxic when applied to the flies than when they were exposed to the residue.

Table 2.—Effectiveness of residues of certain synergists combined with Dilan on glass against stable flies and DDT-resistant house flies.[a]

Synergist and Dosage[b] (mg./sq. ft.)	Per Cent Mortality After 24 Hours	
	House Flies	Stable Flies
Piperonyl butoxide		
12.5	84	100
5	20	93
Propionic acid, alpha-propylpiperonyl ester		
12.5	92	100
5	15	95
Senecioic acid, alpha-allylpiperonyl ester		
12.5	98	100
5	9	70
Dilan alone[c]	0	35
Untreated	0	9

[a] Average of 2 to 4 tests.
[b] Dosage of synergist 5 times that of Dilan.
[c] 400 mg. against house flies and 200 mg. against stable flies.

Table 3.—Effectiveness of residues of certain synergists combined with Dilan on wood against DDT-resistant house flies.[a]

Synergist[b]	Exposure, Hours	Per Cent Mortality After Exposure on Indicated Day After Treatment				
		Initial	3rd	7th	14th	21st
Piperonyl butoxide	2	34	—	—	—	—
	4	82	70	32	56	58
	24	—	95	84	90	85
Propionic acid, alpha-propylpiperonyl ester	2	12	—	—	—	—
	4	64	66	22	28	38
	24	—	94	84	74	74
Senecioic acid, alpha-allylpiperonyl ester	2	8	—	—	—	—
	4	66	42	22	24	36
	24	—	98	74	66	60
None (Dilan alone)	2	0	—	—	—	—
	4	16	2	2	12	14
	24	—	92	50	58	50
Untreated control	4	0	0	0	0	0
	24	0	0	0	0	0

[a] Average of 2 tests.
[b] Dosage of 250 mg. of synergist and 50 mg. of Dilan per square foot.

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The Nature of Lygus Bug Injury to Lima Beans[1]

JOHN C. ELMORE, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Injury to plants by sucking insects has been investigated by many workers. Hawley (1922) established the relationship between the feeding of hemipterous insects and dimpling of bean seeds. King & Cook (1932) observed the effects of the feeding of several sucking insects on the cotton plant. Shull (1933) investigated damage to beans by *Lygus hesperus* Knight and *elisus* Van Duzee. Sorenson (1939) reported on the relation of lygus bugs to alfalfa-seed production, and Jeppson & MacLeod (1946) showed how these bugs affected alfalfa growth. Seed pitting and plant damage were reported by Baker *et al.* (1946). Hills (1943) compared the damage caused by lygus bugs and Say stink bugs to sugar beets grown for seed. The writer conducted experiments in southern California from 1951 to 1954 to learn more about the relation between lygus bug habits and injury to bean plants.

EXPERIMENTAL PROCEDURE.—Naturally infested plants from the fields were dissected and examined under the binocular microscope to determine the nature and extent of injury. These observations were correlated with lygus infestations as determined by the sweeping method. Sweeping was done with a standard 15-inch net. Each stroke covered 8 to 9 feet of a single row or an average of 14 plants. Nymphs and adults were counted after each 10 strokes. Similar examinations were made of plants that had been caged in each field and artificially infested.

COMPARATIVE INJURY BY TWO SPECIES.—Both *Lygus hesperus* and *elisus* occur in the lima bean areas, but *hesperus* has been collected more commonly from lima bean plants. *Lygus elisus* has been numerous in some situations on *Chenopodium* weeds, alfalfa, and sugar beets, and has occasionally invaded lima bean and cowpea fields from these sources, but only a few specimens have been observed in the fields surveyed. The first indication of the greater importance of *hesperus* as pests of beans was obtained in 1951, when like numbers of each species were caged on lima bean plants (Table 1).

FEEDING MECHANISM OF BUGS IN RELATION TO PLANT INJURY.—Lygus bugs have a suctorial type of mouth structure similar to that of other Hemiptera. The long, slender probosis or jointed labrum, which is deeply concave on the anterior surface and fused into a tube at the tip, forms a channel containing four slender bristles, two of which are modified mandibles and the other two maxillary stylets (Muir & Kershaw 1911). These bristles are attached to retractor and protractor muscles and are used to pierce and probe plant tissue for food. The bristles are so tiny that they penetrate plant tissue without forming a visible scar on the surface. The jointed probosis folds back elbowlike, and does not go into the plant. The mandibles are the chief piercing organs. The stylets, which lie closely between the two mandibles, fit together to form two canals, one to carry saliva into the plant and the other to carry food from it.

Table 1.—Comparative injury to shelled lima beans by *Lygus hesperus* and *elisus*.

Lygus SPECIES[a]	CAGES	INJURED BEANS	
		Immature	Mature
	Number	*Per Cent*	*Per Cent*
hesperus			
Adults	9	11.2	2.8
Nymphs	4	20.7	11.0
elisus			
Adults	5	2.1	2.9
Nymphs	3	1.3	1.7

[a] Fifty bugs per cage.

FIG. 1.—Lygus bug damage to lima bean pods and beans.

The material removed for food and the mechanical injury to the plant tissue do not tell the whole story. Lygus bugs also have a strong salivary syringe, or force pump, which forces saliva into plant tissue during feeding. Flemion *et al.* (1952) found that saliva was deposited by *Lygus lineolaris* while feeding on green bean tissue. The nature of this secretion is not known, but Roeder (1953) says that enzymes required by the particular diet of the insect are usually present. According to Wigglesworth (1950), the saliva of *Lygus* species contains two digestive enzymes, invertase and amylase, which act on sugars and starches. This accounts for discolored areas surrounding feeding spots inside green lima bean pods and seeds (Fig. 1). Horsfall (1923) discussed the effects of the feeding punctures of aphids on plant tissues and illustrated the spread of injected material and the breakdown of cell tissue not touched by the piercing organs. Flemion *et al.* (1954) made microscopic observations on the mechanics of feeding, and illustrated the penetration of the stylets into various tissues of the bean pod. They concluded that "many cells in the feeding area were affected—some had collapsed, while others were in various stages of disorganization."

INJURY IN RELATION TO PLANT DEVELOPMENT.—*Field Observations.*—Lygus bugs lay eggs in punctures they make in the main stems of small bean plants even before blossom buds appear (Fig. 2). As the plants develop, they continue to lay their eggs in and feed upon the tender shoots, fruiting terminals, and young pods. Ex-

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FIG. 2.—Stages of plant growth attacked early in the season. In stages A and B stems only are attacked, chiefly at the nodes. In stages C, D, and E pods as well as stems are attacked. Blossoms may fall because of stem injury.

amination on July 8 of small plants from a heavily infested field (0.70 adult and 0.56 nymph per sweep) showed 1 to 5 egg punctures per plant in the main stems near the soil level. Distorted, swollen areas around the punctures indicated that the eggs had been desposited when the plants were small, and their hatching had produced a high nymph population. Of 51 fruiting spikes from more advanced plants from the same field, containing blossom buds and a few blossoms, 18 had one or more egg punctures. Eggs had been laid only in the stems, not in blossom buds. Further observations on July 15 showed 1.01 adults and 1.02 nymphs per sweep. Of a total of 176 pods less than 2 inches long 51 contained 1 to 6 egg punctures. Examination of 673 small pods from this and four other fields showed that 25 per cent of them contained 1 to 6 eggs each when bug populations ranged from 1.5 to 2.9 per sweep. Most of the eggs were in pods less than 2 inches long. Many punctured pods were observed on the ground. If this loss of pods exceeds the plant's ability to replace them, crop loss occurs.

Cage Experiments.—In the first experiment two cages were used, each being placed over two plants. The plants were of the Fordhook variety and had blossom buds, blossoms, and immature pods. Fifty adults of *hesperus* were held in each cage from July 11 to 17, and then the plants were examined. Thirteen per cent of the fruiting stems (racemes) contained 72 per cent of all eggs found, 28 per cent were in immature pods, and none in blossom buds or blossoms. Forty-two per cent of the pods were on the ground because of lygus bug feeding and oviposition.

Four cages were used in the next experiment (July 17 to 23), set up in the same manner over plants of large bush lima beans, except that two cages contained nymphs and the other two adults. The nymphs injured all the pods on the plants, and the adults all but four large pods 3 inches long.

A third cage experiment (July 21 to 31) was set up in a field containing three plantings of Ventura lima beans made 10 days apart. The earliest planting had set pods at the time of the test, a second had only blossom buds and blossoms, and the latest had no blossom buds. In each planting one cage was placed over two or three plants together with 50 *hesperus* adults. The cage over the earliest planting contained 47 pods, and 30 were injured, including 16 which were on the ground. The cage over the second planting contained 50 eggs in various parts of the plants—60 per cent inserted in the stems supporting bud clusters and in stem runners, 26 per cent between blossom buds in bud clusters, 10 per cent in leaf petioles, and 4 per cent in the main stems. None were in blossom buds or blossoms. In the third planting, with no blossom buds, the plants were seriously injured by feeding and oviposition in the main stems but concentrated at the nodes.

Lygus bugs have not been observed feeding or ovipositing in blossoms or blossom buds, but they weaken the tender stems that bear them. When severe, this type of injury causes shedding of buds and blossoms. Similar damage has been observed in thrips injury to onion flowers (Elmore 1949). Onion flowers were destroyed or weakened because thrips attacked flower pedicels and anther filaments. Bean pods are subject to attack by lygus bugs from the time they are formed until they are mature and tough. Pods 2 inches long or smaller are preferred, and often contain 5 or 6 eggs each. Many such pods are shed because of feeding and ovipositing. Extensive injury to young plants may prevent fruiting.

POD DISTORTION.—An important type of injury resulting from lygus bug feeding and oviposition in small pods is stunting and distortion of the surviving pods. Four lima bean fields in which there were one or more bugs per sweep early in July 1952 had 25 per cent or more distorted pods (Fig. 3). Obviously the number of beans in such pods was reduced and many of them were deformed.

In 1952 seven 1/100-acre plots 100 feet apart were dusted with DDT on July 31. Lygus bug populations per sweep were 1.4 on July 16, 1.54 on July 22, and 1.54 on July 31. A preliminary examination of pods 1 to 1½ inches long on July 31 showed that 34 per cent had been injured by lygus bugs. By August 13, 2 weeks after the DDT treatment, 100 pods were collected from each plot and compared with a like number from an untreated area nearby. Twenty-four per cent of the pods from the treated plots were distorted and 29 per cent from untreated plants. There was no significant difference in pod distortion after July 31, but 6 per cent of the shelled

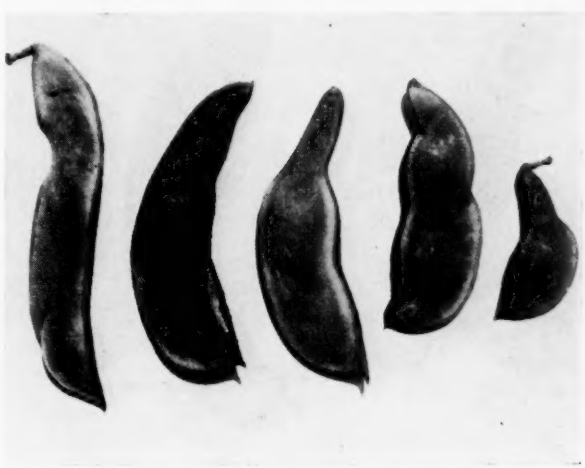

FIG. 3.—Deformed pods caused by lygus bug attack when small.

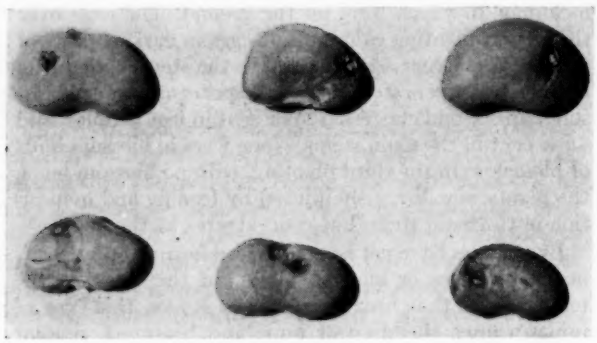

FIG. 4.—Pitted beans showing enlargement of pitted areas due to growth.

beans from the untreated part of the field were pitted compared with 1 per cent of those from the treated plots.

PITTING OF THE BEANS.—Cage experiments and observations indicate that pitting of the beans is caused by feeding of lygus bugs after the seeds have formed. Immature beans, half-size or smaller, may be seriously injured, and the very small ones fail to develop further. The injured areas of those that do develop tend to enlarge in proportion to bean growth (Fig. 4). This type of injury is easily recognized in sorting, and most of the smaller beans are screened out at harvest time. The kind of pitting that shows up in the full-sized beans at harvest time is caused by lygus feeding on pods as they approach the mature green stage (Fig. 5). This information was obtained by caging Fordhook plants 3 to 6 days before harvest for freezing. Each cage contained 2 or 3 plants and 25 adults of *hesperus*. More than twice as many immature pods were damaged as the mature green ones (Table 2). However, from 3 to 30 per cent of the mature green beans were pitted.

These observations agree with those made in the field—that immature pods and the tender parts of the plant are

FIG. 5.—Lima beans showing the type of pitting that is caused by lygus feeding after the beans have reached nearly full size. Punctures in the pods are not apparent.

Table 2.—Damage to shelled green Fordhook lima beans when plants were caged with 25 adult lygus bugs near harvest time.

DATE CAGED	IMMATURE BEANS		MATURE GREEN BEANS		HARVEST DATE	PITTED BEANS FROM UNCAGED PLANTS
	Total	Pitted	Total	Pitted		
	Number	*Per Cent*	*Number*	*Per Cent*		*Per Cent*
Aug. 11–15	75	36	138	12	Aug. 19	0
14–18	38	66	114	6	19	0
14–18	74	27	129	21	Sept. 5	6
18–24	63	62	143	30	Aug. 24	1
21–24	143	6	267	3	29	0
24–29	148	38	272	12	29	0
29–Sept. 4	—	—	296	18	Sept. 5	8

attacked more severely, but that the more mature pods are attacked if the population of lygus bugs is high or if immature pods are scarce. It was also evident that many bean pods become resistant to puncturing as they reach the mature green stage. The pods may show signs of puncturing, but none of the punctures reach the seed. This resistance is due to the formation of a tough membrane in the pod wall, and is probably closely associated with plant-maturity rate.

SUMMARY.—Injury to lima beans by lygus bugs was observed in field and cage experiments in southern California from 1951 to 1954. In this area *Lygus hesperus* Knight causes greater injury than *elisus* Van Duzee.

The feeding mechanism of lygus bugs is fitted with probing bristles which break down plant tissue, and also with a salivary syringe which injects toxic oral secretions. Saliva containing enzymes appears to spread from feeding sites causing discolored areas and injury to plant tissue far beyond that due to probing and sucking.

Lygus bugs oviposit in and feed upon the main stems of small bean plants and on the tender growth terminals as the plants develop. Stems, fruiting spikes, and young pods are attacked, but not blossoms or blossom buds. However, extensive lygus bug feeding and oviposition can cause shedding of blossom buds and young pods, with consequent crop loss.

Injury to small pods causes distortion of those which survive. Although lygus bugs prefer to feed on the tenderest parts of the bean plant, they may also attack pods in the mature green stage and puncture or pit the beans within. A scarcity of small tender pods in relation to lygus bug abundance tends to increase the pitting of beans within the larger pods. Lima bean pods become resistant to attack either during or immediately following the mature green stage.

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Flavor Evaluation and Residue Analysis of Malathion-Treated Lettuce[1]

LEMAC HOPKINS, I. K. ABU YAMAN, and L. A. CARRUTH, *University of Arizona, Tucson*

This study was made to ascertain whether any measurable flavor effects were produced in the harvested crop by malathion applied as an insecticide, and to determine the rate of disappearance of malathion on commercially-grown lettuce.

Malathion was applied in dust and liquid formulations by aircraft on March 9, 1954, and by ground equipment on March 19, 1954, to plots in a commercial lettuce planting near Peoria, Arizona. The unreplicated treated plots were each 4½ acres in extent and separated by large untreated areas to minimize drift contamination.

Sprays were applied at the rate of 2 pints of 57 per cent malathion emulsion concentrate per acre. The concentrate was dissolved in water at the rate of 10 gallons per acre for aircraft and 70 gallons per acre for the ground spray equipment. In each case 1.25 pounds of actual malathion were applied per acre. "Piper Supercub" aircraft were used for the air spraying and dusting operations. Ground applications of dust were made with a Gustafson tractor-mounted duster with tubes which covered six 2-row "beds" of lettuce in one swath. Ground applications of sprays were made with a modified Bean tractor-drawn sprayer with a boom attachment.

Malathion dust of 5 per cent strength was applied at the rate of approximately 35 pounds per acre. Later analyses showed that the amounts of malathion actually present per acre were 1.65 pounds in the air-dusted plots and 1.50 pounds in the ground-dusted plots. At the time of the treatments the lettuce heads were well formed.

RESIDUE MEASUREMENTS.—Samples of lettuce, consisting of five heads per plot, were taken at 0, 3, 7 and 10 days after application for chemical anaylsis to determine the malathion residues which were present. The heads were quartered and one segment from each head was composited, chopped and sub-sampled to a unit of from 200 to 300 grams. Duplicate sub-samples were extracted with carbon tetrachloride and analyzed for malathion (American Cyanamid Company 1954). The sampling of the lettuce treated with ground equipment was discontinued after the 3-day sample was taken, due to rain that apparently washed the malathion from the heads. The residue measurements obtained are summarized in table 1.

SAMPLE COLLECTION AND STORAGE.—Lettuce samples for flavor evaluation tests were collected on March 12 and 16, 1954 or 3 and 7 days after application, respectively, from plots sprayed and dusted by aircraft. Samples from plots sprayed and dusted with ground equipment were collected on March 22 and 31, or 3 and 12 days after application, respectively.

Lettuce samples were stored in refrigerators at normal storage temperature until utilized. The loose outer leaves

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Table 1.—Residue measurements and flavor evaluation of lettuce harvested at different periods after spray and dust applications of malathion. Peoria, Arizona. March, 1954.

METHOD OF APPLICATION	AIRCRAFT				GROUND EQUIPMENT			
FORMULATION,	Dust		Spray		Dust		Spray	
POUNDS PER ACRE	1.65		1.25		1.50		1.25	
Residue Measurements					*Parts Per Million*			
0 days after application	65.0		68.1		85.0		125.0	
3 days after application	1.6		4.1		0.0		0.0	
7 days after application	0.5		2.4		—[a]			
10 days after application	0.0		0.0					
Flavor Evaluations								
Harvest date (days after treatment)	3	7	3	7	3	12	3	12
Total no. of samplings	30	60	30	60	60	60	60	60
No. of replicates	2	4	2	4	4	4	4	4
No. of correct separations of treated and untreated lettuce[b]	11	20	12	23	27	21	17	20
No. of correct separations in which untreated sample was preferred[b]	6	10	9	8	18	14	11	12

[a] The plots treated with ground equipment were not sampled beyond a period of 3 days after application because of a rain that apparently washed the malathion residues from the lettuce heads.
[b] There was no significant difference at the 5% level.

were removed, and the heads were then washed with tap water. Only the outer four or five leaves were used for test samples after being cut into small pieces.

FLAVOR EVALUATIONS.—Flavor evaluations were made by the triangular method according to the "standard" technique sponsored by the National Canners Association (1954). Each triangular sequence consisted of three coded samples, identical in appearance but actually consisting of either two treated samples and an untreated sample, or two untreated samples and one treated sample.

A taste-testing panel was organized with the cooperation of staff members, graduate students, and undergraduates at the University of Arizona. From a group of 30 volunteers, a panel of 15 persons was selected for each evaluation test. A majority of the judges were the same on each occasion. Panel members were chosen for their ability to correctly separate treated and untreated lettuce during a preliminary test which involved four triangular sequences served at two sessions. Those with less accurate judgments were not used in later tests.

The individual judgments of each triangular sequence were recorded on a standard form, which was developed by the cooperating members of a project on methodology of flavor evaluations sponsored by the Raw Products Research Bureau of the National Canners Association and made available by Dr. C. H. Mahoney of that organization.

During each session the judges were asked to evaluate two "triangular" sequences. The judges were instructed to determine, if possible, which two samples in each sequence were identical. They were asked to taste the coded samples slowly from left to right, and to rinse the mouth with water between each sample. It was permissible to retaste samples as desired and in any order. In addition to determining the identical samples, the judges were asked to indicate which samples were preferred in each sequence. They were also asked to indicate what they considered to be the "degree of objectionability" of the less-preferred samples.

Four replicate evaluations of triangular sequences, including treated and untreated lettuce, were made for: each method of application, each harvest date, each formulation of malathion—except that only two replicates were possible for the samples taken from the airplane-treated plots (both sprayed and dusted) the third day after treatment.

The flavor evaluation data are summarized in table 1. The numbers of correct separations between treated and untreated lettuce were analyzed for significance according to the table of Roessler, *et al.* (1948). The numbers of correct separations in which also the untreated samples were preferred were analyzed for significance according to the table of Blum & Swanson (1954). An approximate measure of the relative objectionability of each series was also determined on the basis of preference recorded. The "objectionability" ratings were not significant enough to indicate any consistent objection to the quality of either the treated or untreated lettuce.

RESIDUE DISAPPEARANCE.—There was a rapid disappearance of malathion residues following the various applications. No traces of malathion were found in samples collected 3 days after treatment with ground application equipment. Residues persisted slightly when applied from aircraft. The greatest loss occurred within 3 days after application, and after 10 days no measurable residues were present. These observations indicate that malathion can probably be used with safety when applied to an edible crop such as lettuce to control insect infestations occurring shortly before harvest.

CONCLUSION.—The flavor evaluation tests were in agreement with the residue determinations, and indicate that no measurable effects could be found on lettuce harvested from 3 to 12 days after treatment with effective recommended dosages of malathion.

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Improved Deposits for Controlling Insects Outdoors[1]

W. N. Sullivan, Irwin Hornstein, A. H. Yeomans,[2] and Ching-Hsi Tsao, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Investigations by Hadaway & Barlow (1947, 1949) and Horstein *et al.* (1954) have shown that deposits of insecticides on foliage outdoors are unsatisfactory in moist climates whether applied in an oil solution, a suspension, or a stable emulsion. Oil solutions are absorbed into the interior of the leaves, and rain within a few days after application has a tendency to wash off suspensions and emulsions. In addition, oils and emulsions may burn foliage. Hornstein *et al.* (1954) recently described a method of applying insecticides on outdoor foliage in emulsions containing a low-boiling oil phase and unstable emulsifying agents. The present paper describes a method of obtaining nonpenetrating and persistent residues by incorporating a chlorinated terphenyl as an extender for the more volatile insecticides, and applying the mixture in a low boiling solvent such as methyl ethyl ketone.

Tests with Various Formulations.—In the first series of tests the residual effectiveness of various formulations against house flies, *Musca domestica* L., was determined by applying them at close range with a standard Peet-Grady type atomizer connected to a tank supplying air at approximately 25 pounds per square inch. Both nonvolatile (DDT) and volatile (lindane and aldrin) chlorinated hydrocarbons were tested in methyl ethyl ketone solutions, alone and in combination with a chlorinated terphenyl (Aroclor 5460). DDT was also tested in a 5 per cent solution in No. 2 fuel oil and in an emulsion prepared by diluting a 25 per cent emulsifiable concentrate 1:2 with water. Nine grams of oil-soluble dye (Dupont oil red) were added to each gallon of spray for use in spray-deposit determinations.

The sprays were applied in duplicate to branches with a southern exposure in a grove of pine trees planted in a square plot on the top of a hill surrounded by grassland or on branches exposed to the west in a spruce windbreak. Representative foliage samples from the sprayed branches, usually one or two twigs, were brought into the laboratory, placed in pint Mason jars with cheesecloth covers, and a batch of 50 to 100 flies, temporarily immobilized with carbon dioxide, was placed in each jar. After 30 minutes' exposure the flies were transferred to cages and held for a 24-hour observation period.

For determination of the spray deposits, aluminum plates 1 square foot in area were exposed in the field alongside the branches so that they would receive a proportionate amount of spray. The deposit on each plate was washed with acetone into a 100-ml. volumetric flask, and the amount of dye determined spectrophotometrically in an appropriate aliquot of this solution. Since the ratio of insecticide to dye in the spray solution or emulsion was known, once the amount of dye on the square-foot plate was determined the amount of insecticide could readily be calculated. The meterological conditions during the tests are given in table 1.

As shown in table 2, lindane and aldrin evaporated so rapidly that they were effective for less than 10 days. However, the incorporation of the film-forming chlorinated terphenyl extended their effective life many-fold, as also shown by Tsao *et al.* (1953). Residues 102 days old from 1:1 mixtures of lindane or aldrin and chlorinated terphenyl gave 99 and 100 per cent mortality of house flies while the 1:0.125 mixtures were intermediate in effectiveness. It is interesting to note that the residual effectiveness of nonvolatile DDT was not helped when chlorinated terphenyl was included in the spray. The toxicity of the 1:1 DDT-chlorinated terphenyl mixture was much lower than that of DDT alone or the 1:0.125 mixture, especially when the deposits were aged. However, when extracts of the 102-day-old residues obtained by washing the treated twigs in acetone were assayed with house flies, the 1:1 mixture gave much higher (95

Table 1.—Meterological conditions during the test period. Agricultural Research Center, Beltsville, Md.

Period	Mean Daily Temperature (° F.)	Rainfall (Inches)
1953		
Sept. 20–26	48–73	0
Sept. 27 to Oct. 3	49–80	0
Oct. 4–10	40–68	0.03 (Oct. 5) 0.25 (Oct. 7)
Oct. 11–17	39–73	0.01
Oct. 18–24	44–74	0.02
Oct. 25–31	43–66	0.8 (Oct. 28) 1.4 (Oct. 29) 1.28 (Oct. 30)
Nov. 1–7	33–57	0.6 (Nov. 6)[a]
Nov. 8–14	24–53	0
Nov. 15–21	31–70	0
Nov. 22–28	35–53	0.6 (Nov. 23) 0.3 (Nov. 25)
Nov. 29 to Dec. 5	27–50	0.03
Dec. 6–12	29–57	0.87 (Dec. 7) 0.51 (Dec. 10)
Dec. 13–19	23–39	0.70 (Dec. 13) 1.13 (Dec. 14)
Dec. 20–26	23–47	0.02
1954		
Dec. 27 to Jan. 2	25–48	0
Jan. 3–9	25–45	0.01

[a] Snow.

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[2] Now with Agricultural Marketing Service, U.S.D.A.

Table 2.—Residual effectiveness against house flies of methyl ethyl ketone solutions of insecticides,[a] alone and in combination with chlorinated terphenyl.

Formulation (Pounds in 1 Gallon of Methyl Ethyl Ketone)		Insecticide Deposited (Mg. per Square Foot)	Per Cent Kill by Residue of Indicated Age (Days)					
Insecticide	Chlorinated terphenyl		3–4	10	30	39	60	102
DDT								
1	0	22	99	97	100	84	59	51
1	1	15	63	49	53	49	17	3
1	0.125	15	95	95	100	83	18	50
Lindane								
1	0	22	91	8	0	—	—	—
1	1	13	100	100	100	100	100	99
1	0.125	23	100	100	96	85	50	28
Aldrin								
1	0	21	100	5	0	—	—	—
1	1	18	100	100	100	100	100	100
1	0.125	29	100	100	93	35	74	55

[a] Applied to pine twigs on September 25, 1953.

per cent) mortality than the other two DDT formulations (about 30 per cent). This can be explained by assuming that DDT that has become decomposed or masked by foreign materials remains in the film surface and decreases the toxicity of the deposit. In contrast, insecticides with relatively high vapor pressure renew the toxicant in the film surface by the slow diffusion of fresh insecticide from the body to the surface of the film.

The advantages of methyl ethyl ketone were apparent in the results with DDT (Table 3). The nonpenetrating, persistent deposits from this solution gave good control long after deposits from DDT in fuel oil were ineffective.

Dispersion Experiments.—The second series of tests consisted of dispersion studies of concentrated insecticide-chlorinated terphenyl formulations applied with a knapsack sprayer equipped with a hollow-cone, Whirljet-type airplane spray nozzle placed in the center of the air stream from a Buffalo mist blower. The machine was driven at about 5 miles per hour at right angles to the wind direction. The spray materials consisted of the following mixtures dissolved in 1 gallon of methyl ethyl ketone: 3.5 pounds of a 4:1 DDT-lindane mixture plus 3.5 pounds of chlorinated terphenyl and 4 pounds of DDT plus 4 pounds of chlorinated terphenyl.

In these tests 3- by 5-inch cards were placed at 10-foot intervals along an airport runway in line with a 20-mile-per-hour wind. The mist blower was slowly pulled by a truck along a course perpendicular to these cards. The spray pattern was then determined by visual inspection. The 4:1 DDT-lindane mixture gave a deposit at 235 feet sufficient to kill flies. The particle size ranged from 114 microns at 25 feet to 35 microns at 225 feet. The DDT mixture began deposition 20 feet from the mist blower, peaked at 110 feet, was 30 per cent of peak at 300 feet, and there was some deposit at 400 feet.

Table 3.—Residual effectiveness against house flies of various formulations of DDT.

DDT Formulation	Insecticide Deposited (Mg. per Square Foot)	Per Cent Kill by Residues of Indicated Age (Days)						
		3–4	10	15	30	39	67	78
Applied to pine twigs on October 19, 1953								
Emulsion	11	100	—	91	99	97	—	93
Methyl ethyl ketone solution	7.7	100	—	96	100	99	—	90
No. 2 fuel oil solution	26	100	—	48	42	37	—	0
Applied to spruce twigs on October 30, 1953								
Emulsion	7	66	71	—	68	—	0	—
Methyl ethyl ketone solution	11.5	96	98	—	92	—	92	—
No. 2 fuel oil solution	9.5	1	1	—	3	—	1	—

Because of the high solids content, evaporation of just a small amount of the solvent leaves semi-solid spheres which travel through the air with little change in dimensions due to further solvent evaporation. These spheres are uniform in size and deposit as sticky balls about 100 microns in diameter. Except for slight flattening on alighting, these balls maintain their shape for several days before flattening out on the treated surface. Microscopic examination of treated cardboard and kraft paper showed that these balls adhered to the surface without penetration. This method might therefore be used in applying pesticides as nonpenetrating residues on leaves, wood, paper, mud, and similar surfaces. Particles of this type may also be suited for airplane application by using methylene chloride or methyl chloroform or a mixture of the two instead of the flammable methyl ethyl ketone.

Conclusions.—Deposits of DDT may remain toxic for a longer period on foliage when applied in a methyl ethyl ketone solution than in fuel oil.

High concentrations of insecticide-chlorinated terphenyl mixtures in methyl ethyl ketone on spraying produce small, sticky balls, which travel for considerable distances without much change in particle size and do not penetrate porous surfaces.

The residual properties of lindane and aldrin sprays are greatly improved when mixed with chlorinated terphenyl.

Summary.—The residual effectiveness on outdoor foliage of both nonvolatile (DDT) and volatile (lindane and aldrin) chlorinated organic insecticides, alone and in combination with a chlorinated terphenyl was determined. This was done by spraying methyl ethyl ketone solutions of the insecticide mixtures on pine branches outdoors and periodically collecting twigs for indoor tests on house flies, *Musca domestica* L. DDT was also applied in fuel oil and in an emulsion for comparative purposes. It was found that a chlorinated terphenyl greatly extended the residual life of lindane and aldrin but DDT was not helped. Surface residues from methyl ethyl ketone solutions of DDT lasted longer, however, than fuel oil applications.

The problem of applying insecticides in highly volatile solvents was apparently overcome by the use of very concentrated solutions of insecticide and chlorinated terphenyl. Evaporation of a small amount of the solvent left semisolid spheres about 100 microns in size, which dispersed well and adhered tenaciously, without penetration of the surface on which they landed.

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Response of Insects to Ultra Violet Lights[1]

S. W. FROST, *The Pennsylvania State University, State College*

These experiments are a continuation of those reported in 1953[2] and 1954.[3] During the summer of 1954, three Minnesota traps were operated in a somewhat open area shielded from nearby street and other lights at State College, Pa. They were hung 6 feet from the ground on a metal standard (Fig. 1). The position of the traps was changed once a week so that each trap maintained the middle and end positions for equal periods of time. They were operated continuously for 64 nights from May 29 to August 13. The lights were controlled by a time switch which turned them on, and off, simultaneously. The operation period varied from 8:30 or 9 P.M. to 4:30 or 5 A.M. depending upon the intensity of the daylight at various periods of the summer. All the insects captured were identified to order, family and when desirable to species.

Three types of ultra violet lamps were used namely, 100 watt BH_4, 100 watt AH_4 and $2\frac{1}{2}$ watt AR_1. The BH_4 had a built in red-purple filter eliminating most of the visible rays. As the AH_4 is manufactured without a filter this lamp was equipped with a special tubular red-purple filter supplied by the Corning Glass Works. The two AR_1 lamps used in one trap operated on 110 volts. The AH_4 and BH_4 lamps required General Electric ballast #89G140 which provided the required electrical characteristics for lamp starting and operation. The energy distribution of these lamps is shown in table 1.

FIG. 1.—Arrangement of traps for ultra violet studies.

Table 1.—Spectral energy distribution of the ultra violet lamps used during 1954.

SPECTRUM	WAVE LENGTH IN ANSGTROMS	PER CENT OF LAMP WATTS		
		BH_4	AH_4[a]	AR_1
Ultra violet	2,800– 3,200	.001	.72	.20
Ultra violet	3,200– 3,800	.83	4.30	3.19
Violet	3,800– 5,000	.03	4.60	.35
G, Y, O. R.	5,000– 7,600	.04	5.83	.00
Infra red	7,600–50,000	.00	.00	.00

[a] Without the Corning red-purple filter No. 5874 which transmits 60 per cent of the spectrum between 3550 and 3700 Angstroms. With the filter the visible rays no doubt simulated those of the BH_4 lamp.

Table 2 summarizes the catches for 1954. In comparing these figures, factors such as temperature, wind velocity, barometric pressure and precipitation can be eliminated as all the traps were operated in the same location. Unfavorable conditions, especially high wind velocities and low temperatures affect catches on individual nights. Compared with previous years, the summer of 1954 was very unfavorable for operating light traps. The nights were unusually cool and the catches were considerably lower than during former summers. The location of the traps in the Borough of State College was unfavorable for trapping certain insects such as European corn borers, tomato sphinx moths and cucumber beetles.

In preparing table 2, only insects that responded in significant numbers were included separately. Many insects have been grouped under larger headings. The midges include Cecidomyidae, Chironomidae, Simuliidae, Psychodidae and Ceratopogonidae. The Scarabaeidae consisted chiefly of species of *Aphodius*. Only 40 Phyllophaga were taken in all the traps during the entire period. The Noctuidae include species of *Autographa, Noctua c-nigrum, Agrotis ypsilon, Feltia subgothica*. Of these only 128 specimens were taken during the summer. The macrolepidoptera include *Desmia funeralis, Hyphantria cunea, Halisidota caryae* and a few other unimportant species. The Hymenoptera consisted almost entirely of parasitic species, Ichneumonidae, and a few ants. Other

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[2] Jour. Econ. Ent. 46(2): 376–7,1953.

[3] Jour. Econ. Ent. 47(2): 275–8, 1954.

Table 2.—Summary of insects attracted to ultra violet, summer of 1954, State College, Pa.

INSECTS	AH4	BH4	AR1
Culicidae	27	18	1
Midges[a]	37,564	40,014	577
Tupulidae	161	162	5
Anthomyiidae	629	553	25
Borboridae	525	652	5
Drosophilidae	1,007	1,049	8
Lonchopteridae	514	573	3
Chloropidae	26	30	5
Misc. Diptera	2,247	2,247	63
Total Diptera	42,700	45,298	692
Carabidae	370	370	173
Staphylinidae	901	1,088	118
Curculionidae	22	36	7
Scolytidae	29	39	8
Berosus	21	23	3
Lampyridae	18	28	9
Scarabaeidae	133	99	30
Elateridae	56	65	18
Elm leaf beetle	278	337	41
Misc. Coleoptera	1,616	1,884	378
Total Coleoptera	3,444	3,969	785
Aphididae	488	522	38
Cicadellidae	7,839	9,005	221
Total Homoptera	8,327	9,527	259
Miridae	404	425	108
Misc. Heteroptera	109	89	15
Total Heteroptera	513	514	123
Crambidae	938	1,107	292
Sphingidae	11	13	5
C. pomonella	55	62	13
Tortricidae	37	66	18
L. unipuncta	129	152	99
M. americana	50	52	44
Noctuidae	203	333	196
Micro. Lepidoptera	1,989	2,626	241
Macr. Lepidoptera	131	225	110
Total Lepidoptera	3,543	4,636	1,018
Psocidae	132	148	17
Micro. Trichoptera	2,454	3,122	48
Macro. Trichoptera	943	1,225	168
Total Trichoptera	3,397	4,347	216
Hymenoptera	832	1004	46
Totals	62,888	69,443	3,156

[a] Consult discussion of table.

insects include Plecoptera, Chrysopidae, Ephemerida and Hemerobiidae, all totaling only 64 specimens. Of these, it is known that the Plecoptera do not respond freely to lights. The Ephemerida come only when lights are placed close to streams or ponds. The Chrysopidae and Hemerobiidae, as noted in 1953, come more freely to white lights. The Heteroptera include chiefly the tarnished plant bug *Lygus lineolaris*, the rapid plant bug *Adelphocoris rapidus*, and the plant bug *Trigonotylus ruficornis*.

SUMMARY.—From the figures presented in table 3, it is very evident that there was little difference in the attractiveness of insects by the AH_4 and the BH_4 lamps. The stronger rays between 2800 and 3800 Angstroms added no particular advantage. As a matter of fact the AH_4 lamp was slightly less efficient than the BH_4 lamp. In the case of the Lepidoptera and the Trichoptera the BH_4 lamp was noticeably more attractive than in the case of the other insects. The catches from the two $2\frac{1}{2}$ watt AR1 lamps used in a single trap did not compare in numbers with those from the other ultra violet lamps.

Table 3.—Relative per cent of species of various orders attracted to ultraviolet lights.

ORDER	AH4	BH4	AR1	TOTAL
Diptera	48.0	51.0	0.7	99.7
Coleoptera	42.0	48.4	9.6	100.0
Homoptera	45.8	52.0	1.4	99.2
Heteroptera	44.6	44.6	10.6	99.8
Lepidoptera	38.5	50.4	11.0	99.9
Trichoptera	42.6	54.6	2.7	99.9
Hymenoptera	44.3	53.5	2.1	99.9
Other insects	42.9	54.2	2.6	99.7
Total insects	46.4	51.2	2.3	99.9

BOOK REVIEW

THE PLANT QUARANTINE PROBLEM, W. A. McCubbin, Ejnar Munksgaard, 1954, Copenhagen, Denmark. American distributors, The Chronica Botanica Co., Waltham 54, Mass., U.S.A. Da. Kr 32—Sh. 33/9—$4.80.

At long last we have a book on this challenging subject by one well qualified to undertake its preparation. Its author participated for many years in plant quarantine enforcement in the State of Pennsylvania and in the Federal Bureau of Entomology and Plant Quarantine. This unusual experience enabled him to approach the subject with state, federal and international problems in mind. While there are numerous papers on various phases of the plant quarantine problem this represents the first attempt to handle the subject as a composite whole.

The book is easy to read, the subject matter being well organized and presented in a clear and pleasing manner. In the preface the author states in part—"It is the purpose of this outline to gather together and present as simply as possible all the essential loose ends of the subject . . . ." This he has done admirably. The book should be of value to laymen, professional workers and teachers.

E. R. SASSCER

Tests with Acaricides against the Brown Wheat Mite[1,2]

CHAS. F. HENDERSON, *Entomology Research Branch, Agr. Res. Ser., U.S.D.A.*, and ELVIN W. TILTON, *Kansas State College*[3]

The brown wheat mite, *Petrobia latens* (Müller), is a pest of dryland wheat in the south-central portion of the Great Plains and the east-central portion of the western plateaus of the United States. According to Fenton (1951), this pest has caused considerable damage to wheat in Oklahoma, serious trouble having been experienced in the panhandle and in most western counties of that State. Knowlton & Tibbetts (1952) stated that this mite caused a substantial amount of injury to many thousand acres of dryland wheat in Salt Lake, Juab, Toele, and San Juan counties of Utah during 1951. In the spring of 1952 the writers observed heavy mite infestations and severe foliage injury on thousands of acres of wheat in Texas County, Okla., and in Morton, Stevens, Seward, Meade, and Haskell counties, Kan. In 1953 the heavily infested area also included Gray, Grant, Stanton, and Hamilton counties, Kan., and Baca County, Colo. However, because of the extreme drouth in the infested area, it was not possible to determine how much of the damage was caused by the mite.

Previous tests on the control of this pest with acaricide dusts were reported by Reynolds & Swift (1951), and those with dusts and sprays by Fenton (1951). Parathion gave the best results when dusts were applied, although at high temperatures (85 to 100° F.) sulfur was almost as effective at the dosages used. The only sprays tested were parathion and TEPP, applied at 0.13 pound in 31 to 33 gallons per acre. These treatments resulted in unsatisfactory control. In the present studies 18 different chemicals[4] were applied against the brown wheat mite. The work was conducted during 1952 and 1953 in field plots located in Finney, Stevens, and Haskell counties of Southwestern Kansas.

Table 1.—**Effect of acaricide sprays against *Petrobia latens* on fall-planted wheat, Moscow, Kan. 1952.**

Acaricide	Pounds per Acre	Mites Before Treatment[a]	After 6 Days		After 18 Days	
			Number of Mites[a]	Per Cent Control	Number of Mites[a]	Per Cent Control
Parathion	0.50	541	15	94	27	88
	0.25	528	26	91	100	57
Metacide	0.25	580	35	88	127	50
Demeton	0.25	646	39	88	150	47
Schradan	0.50	536	71	74	114	52
BHC (gamma isomer)	0.50	403	138	33	232	0
Endrin	0.15	429	161	27	160	15
TEPP	0.25	498	163	36	225	0
Malathion	0.75	486	192	23	197	8
Compound 923[b]	1.00	349	198	0	111	28
Ovotran	0.50	517	204	23	148	34
Aramite	0.33	536	213	22	145	38
R-242	1.00	428	236	0	248	0
NPD	0.50	720	239	35	196	38
DMC	0.25	518	246	7	222	2
Compound 876[c]	0.50	526	247	8	165	28
Check	—	543	278	—	237	—
L.S.D. 5%	—	—	114	—	63	—
1%	—	—	151	—	84	—

[a] Mites in 20 square inches.
[b] 2,4-dichlorophenyl benzenesulfonate.
[c] 1,1-Bis(*p*-chlorophenyl)2-propyn-l-ol.

METHODS AND EQUIPMENT.—Application was made with a jeep sprayer equipped with a 20-foot boom and having cone-type Spray-jet nozzles 20 inches apart. All treatments were made at a liquid pressure of 30 to 40 pounds per square inch, with the machine traveling at 4 miles per hour. Emulsion sprays were used exclusively. Applications were made at the rate of 8 gallons per acre. Except where otherwise stated, the plots were 1/20-acre in size, each plot was surrounded by a 25-foot untreated border, and all treatments were replicated five times.

Estimates of mite populations before and after treatment were made with a fork sampling device developed for the purpose. The fork has four tines into which are placed $\frac{1}{2}\times 5$-inch glass slides covered with adhesive. The fork is inserted beneath the plant at ground level, and the foliage struck by hand to dislodge the mites. This species drops to the ground when disturbed. The mites caught on the slides are later counted in the laboratory, and the number recorded per square inch of area directly beneath the foliage sampled.

The per cent control due to treatment was calculated by a modification of Abbott's formula:

$$100\left(1-\frac{Ta\times Cb}{Tb\times Ca}\right).$$

Here *Tb* is the number of mites collected per sampling unit before treatment, *Ta* the number collected after treatment, *Cb* the number collected from the check plot before treatment, and *Ca* the number collected from the check plot after treatment of the test plots.

SPRING TESTS, 1952.—Three tests were conducted in Stevens County, Kan., during April and May, to determine the relative effectiveness against the brown wheat mite of various acaricide sprays applied to populations on fall-planted wheat.

The first test was initiated on April 17 at the Crawford farm near Moscow. During the treatment the temperature averaged 65° F. and the wind did not exceed 8 miles per hour. The results are shown in table 1.

Four phosphorus compounds—parathion, Metacide, demeton, and schradan—gave the best reductions in mite populations for the first 6-day period. At the end of 18 days only parathion at 0.5 pound per acre gave satisfactory control. Poor reductions were shown by all other materials tested, including the phosphorous compounds TEPP, NPD, and malathion. Among the other unsatis-

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[2] Presented at the meetings of the Southwestern Branch of the Entomological Society of America at Dallas, Tex., February 1–3, 1954.
[3] John P. Edwards assisted in making the mite counts.
[4] Experimental quantities of the various chemicals were supplied by the American Cyanamid Co.; California Spray-Chemical Corp.; Dow Chemical Co.; E. I. duPont deNemours & Co., Inc.; Geigy Co., Inc.; General Chemical Div., Allied Chemical & Dye Corp.; Hercules Powder Co.; Julius Hyman & Co., Inc.; Monsanto Chemical Co.; Niagara Chemical Div., Food Machinery & Chemical Corp.; Naugatuck Chemicals Div., United States Rubber Co.; Pennsylvania Salt Mfg. Co.; Chemagro Corp.; Pittsburgh Agricultural Chemical Co.; John Powell & Co., Inc.; Sherwin-Williams Co.; and Stauffer Chemical Co.

Table 2.—Effect of acaricide sprays[a] against *Petrobia latens* on fall-planted wheat, Hugoton, Kan.

Acaricide	Pounds per Acre	Mites Before Treatment[b]	After 10 Days		After 16 Days	
			Number of Mites[b]	Per Cent Control	Number of Mites[b]	Per Cent Control
Parathion	0.50	152	7	92	2	91
R-242	1.00	188	57	45	14	36
Aramite	0.33	125	66	5	17	0
Compound 923	1.00	127	81	0	8	45
EPN	0.50	168	88	5	36	0
Chlorobenzilate	0.20	204	103	9	22	5
Check	—	156	87	—	18	—
L.S.D. 5%	—	—	41	—	9	—
1%	—	—	56	—	12	—

[a] Applied April 23, 1952.
[b] Mites in 5 square inches.

factory treatments were Ovotran, Aramite, compound 923, and R-242, all of which are sulfur compounds. The effectiveness of compound 923 increased from no control in 6 days to 28 per cent in 18 days and that of Ovotran from 23 to 34 per cent. Reynolds & Swift (1951) also demonstrated that these two acaricides were slow acting, giving better control after 16 days than after 4 to 7 days. BHC, endrin, DMC, and compound 876 were also unsatisfactory.

The second test was initiated on April 23 at the Knier farm south of Hugoton. These plots were 80×109 feet (1/5-acre) and not surrounded by untreated border areas. During treatment the temperature averaged 70° F. and the wind did not exceed 10 miles per hour. Commercially available acaricides were used, as it was desired to know whether any were satisfactory in the event that the immediate use of an acaricide appeared necessary. The results are shown in table 2.

Parathion at 0.5 pound per acre gave the only satisfactory control, being as effective 16 days after treatment as after 10 days. Two materials added since the previous test, EPN and Chlorobenzilate, as well as R-242, Aramite, and compound 923, were ineffective at the dosages employed. As in the first test, compound 923 increased in effectiveness with time.

Table 3.—Effect of acaricide sprays[a] against *Petrobia latens* on fall-planted wheat, Hugoton, Kan.

Acaricide	Pounds per Acre	Mites Before Treatment[b]	After 7 Days	
			Number of Mites[b]	Per Cent Control
Demeton	0.50	86	1	93
Chlorobenzilate	0.38	81	3	84
Parathion	0.50	101	3	87
Ovotran	1.00	93	4	79
Metacide	0.50	104	4	81
Compound 923	2.00	118	7	75
R-242	2.00	89	7	65
Malathion	1.50	73	9	47
Aramite	0.66	129	10	64
Check	—	84	19	—
L.S.D. 5%	—	—	5	—
1%	—	—	7	—

[a] Applied May 3, 1952.
[b] Mites in 5 square inches

On May 3 a second test was conducted on the Knier farm, in which the dosages of R-242, Aramite, compound 923, and Chlorobenzilate applied in the previous test were doubled. Metacide, demeton, malathion, and Ovotran also were included at twice the dosages used in the Crawford test (Table 1). Parathion had given satisfactory control at 0.5 pound in past tests, and was used at that rate as a standard. The experimental design and plot size were the same as in the previous Knier test. During treatment the average temperature was 80° F. and the wind did not exceed 15 miles per hour. The results are shown in table 3.

Demeton at 0.5 pound per acre gave the best control, and parathion at the same rate was second best. Parathion showed practically the same degree of control as in the previous test where an identical dosage was used, whereas the increased dosages of the four commercial acaricides resulted in increased effectiveness. Chlorobenzilate increased from 9 to 84 per cent when the dosage was doubled, compound 923 from 0 to 75 per cent, R-242 from 45 to 65 per cent, and Aramite from 5 to 64 per cent. Metacide and Ovotran also gave fair control, but malathion was unsatisfactory even at the high dosage used.

Counts were again made 20 days after treatment, but by this time populations in all plots were so low that the results were considered inconclusive. Metacide caused some burning of the foliage, but the plants rapidly recovered from this injury. It is believed that the temperature during application (80° F.), as well as the higher dosage used, may have contributed to the foliage burning.

FALL TESTS, 1952.—During October and November three experiments were conducted on the Meairs farm near Sublette, Kan., to determine the effectiveness against the brown wheat mite of various acaricides applied to volunteer wheat under fall conditions.

In the first test application was made on October 20. Ovotran, Metacide, compound 923, R-242, malathion, and Aramite were applied at the heavier dosages used in the second Knier test. The dosage of Chlorobenzilate was increased from 0.38 to 0.50 pound per acre. In addition, the following materials were applied at twice the dosages used in the Crawford test: NPD, DMC, TEPP, endrin, and BHC. Parathion, demeton, and schradan were applied at the original dosages. Flat rather than cone-type nozzles were used. The results are shown in table 4.

Parathion at 0.5 pound per acre gave the best control of mites in all stages 4 and 10 days after treatment. Demeton at 0.25 pound was next, being somewhat more effective 4 days after treatment than parathion applied at the same rate, but less effective after 10 days. As in previous tests, Metacide and schradan were among the best materials tested, with Chlorobenzilate and NPD about equal at the dosages used. The other materials were less effective, even at the high dosages. Again the effectiveness of compound 923 and Ovotran increased with time.

The general level of control was lower than in the tests conducted during the spring. This was believed to have been due, at least in part, to the rapid hatching of the summer eggs of this mite. It has been determined that high populations of these eggs are deposited in the soil during the spring, and hatch in the fall upon contact with free moisture. The first counts were made 4 days after

Table 4.—Effect of acaricide sprays[a] against *Petrobia latens* on volunteer wheat, Sublette, Kan.

Acaricide	Pounds per Acre	Mites Before Treatment[b]	After 4 Days			After 10 Days		
			Number of Mites[b]	Per Cent Control		Number of Mites[b]	Per Cent Control	
				All Mites	Mature Mites		All Mites	Mature Mites
Parathion	0.50	130	53	75	95	71	72	81
Demeton	0.25	109	54	70	92	96	55	77
Parathion	0.25	117	76	61	72	81	65	9
Chlorobenzilate	0.50	114	93	51	54	172	23	0
Metacide	0.50	119	95	52	71	123	47	44
Schradan	0.50	127	98	54	61	133	46	12
R-242	2.00	115	111	42	60	139	38	0
NPD	1.00	139	112	52	58	147	46	0
DMC	0.50	120	126	37	43	196	16	0
TEPP	0.50	116	128	34	51	160	29	0
Endrin	0.30	102	133	22	34	228	0	0
EPN	0.50	130	139	36	42	224	11	0
Aramite	0.66	134	146	35	50	173	34	0
Malathion	1.50	122	149	27	30	182	24	0
Compound 923	2.00	121	150	26	30	77	67	21
Ovotran	1.00	110	153	17	47	110	49	0
BHC (gamma isomer)	1.00	106	163	8	0	243	0	0
Toxaphene	3.00	123	166	19	19	194	19	0
Check	—	106	176	—	—	206	—	—
L.S.D. 5%	—	—	38	—	—	57	—	—
1%	—	—	51	—	—	75	—	—

[a] Applied October 20, 1952.
[b] Mites in 20 square inches.

treatment, and many of the mites had just hatched. As the presence of these newly hatched mites would mask the immediate effect of control, separate counts were kept of mature and immature stages on each sampling date. The results of these counts also are shown in table 4. The control indicated for mature mites 4 days after treatment was considerably higher than that when all stages were considered, particularly with the more effective materials. This supports the conclusion that the hatching in the fall of eggs deposited in the spring tends to mask the immediate effect of a fall treatment. Ten days after application the indicated control of mature mites was much lower than that of all mites for most of the materials used.

Parathion at 0.5 pound per acre applied to 22×100-foot plots surrounded by 25-foot untreated borders resulted in a control of only 75 per cent 4 days after treatment. As the plots were narrow, and less than half the entire area was treated, this was considered a severe test for the acaricides used. To learn whether control would be appreciably increased on a larger area, a second test was conducted in which application was made on November 3 to 125×125-foot ($\frac{1}{3}$-acre) plots of volunteer wheat. In this test cone-type nozzles were used. Four plots received parathion at 0.5 pound per acre, and five alternate plots remained untreated as checks. Population counts made in the centers of these plots 2 and 5 days after treatment indicated control of 74 and 79 per cent, respectively, which were similar to those achieved in the 1/20-acre plots surrounded by untreated areas. This indicates that movement of mites into the 22-foot strips from the border areas was not appreciably greater than into the 125-square foot plots.

The third test was made to see if one type of nozzle was more satisfactory than the other. On November 4, 1/20-acre plots of volunteer wheat received parathion at 0.5 pound per acre with flat nozzles, and five plots received the same dosage with cone-type nozzles. During this test the temperature averaged 58° F. and the wind did not exceed 13 miles per hour. To obtain 8 gallons of spray per acre, a liquid pressure of 21 pounds per square inch was required for the flat nozzles and 47 for the cone-type. A slightly higher gallonage per acre was applied with the flat nozzles.

There was no significant difference in populations in plots treated with the two types of nozzles 3 days after application. As the farmers in the area are equipped with flat nozzles for weed control, this information is of particular interest.

SPRING TESTS, 1953.—In April and May two acaricide tests were conducted at the Chaffin farm, near Sublette, Kan.

On April 22 an experiment was initiated to determine the effectiveness against the brown wheat mite of several chlorinated hydrocarbon insecticides not known to have any appreciable acaricidal qualities. Parathion was applied at 0.5 pound per acre as a standard. As compound 923 had appeared to have some residual effect in past tests, this material was combined with parathion in an attempt to produce an acaricide having longer residual action. DMC and Chlorobenzilate were included, as it was considered that these two acaricides had not received sufficient attention in past experiments. The results are shown in table 5.

The chlorinated hydrocarbon insecticides—chlordane, dieldrin, aldrin, and DDT—were ineffective even at the high dosages employed. DMC and Chlorobenzilate were

Table 5.—Effect of acaricide and insecticide sprays[a] against *Petrobia latens* on volunteer wheat, Sublette, Kan.

Acaricide	Pounds per Acre	Mites Before Treatment[b]	After 3 Days		After 10 Days		After 15 Days	
			Number of Mites[b]	Per Cent Control	Number of Mites[b]	Per Cent Control	Number of Mites[b]	Per Cent Control
Parathion	0.50	110	24	74	16	61	23	41
Parathion+Compound 923	0.25+1.00	93	30	63	19	46	24	27
Chlordane	1.00	70	49	18	27	0	25	0
Dieldrin	0.25	104	57	36	26	31	28	25
DMC	0.50	118	65	37	29	35	36	15
Aldrin	0.50	88	66	13	32	3	27	14
Chlorobenzilate	0.75	110	66	30	27	33	22	43
DDT	2.00	90	69	11	45	0	51	0
Check	—	88	75	—	33	—	31	—
L.S.D. 5%	—	—	27	—	16	—	16	—
1%	—	—	36	—	21	—	21	—

[a] Applied April 22, 1953.
[b] Mites in 5 square inches.

also unsatisfactory. Although parathion was the only satisfactory material tested, the control achieved with 0.5 pound per acre was poorer than in previous spray tests conducted during the spring. Application was made on a warm, clear day with a wind of approximately 12 to 15 miles per hour. However, rain during the night and morning following treatment could account for the lack of better control. Parathion at 0.25 pound plus compound 923 at 1 pound per acre was not so effective as parathion alone at 0.5 pound. Furthermore, there was no indication that this combination had any residual quality. It appeared that the increase in effectiveness with time shown by compound 923 in past tests was due to slowness of action rather than residual quality. Counts made 10 and 15 days after treatment indicated a gradual reduction in control for all materials except Chlorobenzilate, which showed a slight increase.

On April 30 a test was conducted to compare the effectiveness of parathion with that of methyl parathion, which is less toxic to warmblooded animals. Parathion was also tested at higher dosages. Previous tests had shown that Metacide was less effective than parathion against the brown wheat mite. Therefore, it was believed that methyl parathion would be less effective than parathion. Application was made to triplicated 1/20-acre plots of volunteer wheat. The results are shown in table 6.

Table 6.—Comparative effectiveness of parathion[a] and methyl parathion against *Petrobia latens* on volunteer wheat, Sublette, Kan.

Acaricide	Pounds per Acre	Mites Before Treatment[b]	After 2 Days		After 6–7 Days	
			Number of Mites[b]	Per Cent Control	Number of Mites[b]	Per Cent Control
Parathion	1.00	28	3	88	3	84
	0.75	23	4	80	5	68
	0.50	29	7	71	8	60
Methyl parathion	0.50	31	15	36	15	29
Check	—	28	22	—	19	—
L.S.D. 5%	—	—	7	—	3	—
1%	—	—	11	—	5	—

[a] Applied April 30, 1953.
[b] Mites in 5 square inches.

There was a positive correlation between dosages of parathion and reductions in mite populations. After 6 to 7 days parathion at 1 pound per acre continued to give good control, whereas control was appreciably reduced when 0.5 and 0.75 pound per acre were used. At 0.5 pound per acre parathion was much superior to methyl parathion.

Large-Scale Applications, 1953.—On April 30, 1-acre plots in five fields of fallow-land wheat in Finney and Stevens counties, Kan., were treated with parathion at 1 pound per acre. The following percentages of control in the plots were determined:

Field	After 2 Days	After 8 Days
Lynch	93	99
Rower	99	95
Thomas	100	100
Thomas-east	98	94
Crouse	99	95

An experiment was initiated to determine whether one application of parathion over a large area would be sufficient to keep the brown wheat mite under control. On April 9 and 11, 27.5 acres of fall-planted wheat near Johnson, Kan., received 0.6 pound of parathion per acre. The remaining 27.5 acres of the field were left untreated as a check. During treatment there was a cold wind of 25 miles per hour. Four days later there was an indicated control of 89 per cent, and 31 days later it was reduced to 76 per cent. Considering the extremely unfavorable weather during and after the application, it is believed that the control in this large acreage was better than would have been achieved in smaller plots under similar conditions.

Conclusion.—Although demeton and parathion were the most satisfactory materials tested, an acaricide having a longer lasting quality and greater efficiency at low temperatures would be preferable. However, when all factors are considered, parathion is the most practical material of all those yet tested to control this pest.

SUMMARY.—During the spring and fall of 1952 and the spring of 1953, several spray tests with ground equipment were conducted to evaluate the effectiveness of various acaricides against the brown wheat mite, *Petrobia latens* (Müller).

The order of effectiveness was as follows (figures indicate pounds per acre): Demeton 0.5 > parathion 0.5 > parathion 0.25 = demeton 0.25 > Metacide 0.25–0.50 = schradan 0.50 > NPD 0.5–1.0 > Chlorobenzilate 0.50 = Aramite 0.33–0.66 = Ovotran 0.5–1.0 = compound 923 1.0–2.0 > TEPP 0.25–0.50 = EPN 0.50 = malathion 0.75–1.50 = R-242 1.0–2.0 = toxaphene 3.0 = compound 876 0.50 = endrin 0.15–0.30 = DMC 0.25–0.50 > BHC 0.5–1.0. These ratings are based on counts made approximately 5 days and again 2 weeks after treatment, and therefore indicate residual as well as initial effectiveness.

The best control was given by phosphorus compounds, although some were unsatisfactory. Sulfur compounds and chlorinated hydrocarbon insecticides were of little value against this pest. Methyl parathion was compared with parathion and found to be much less effective.

Compound 923 and Ovotran are apparently slow-acting materials. However, when combined with parathion, the former showed no appreciable residual quality.

Flat and cone-type nozzles gave about the same control when 0.5 pound of parathion was applied per acre. Because of the rapid hatching in the fall of eggs deposited during the spring, control with an acaricide having poor residual quality would probably be achieved best in the spring.

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Biology and Control of *Polistes exclamans* Viereck in Arizona Citrus Groves[1]

LEMAC HOPKINS,[2] *University of Arizona Agricultural Experiment Station, Mesa*

In recent years the Vespid wasp, *Polistes exclamans* Viereck, has become increasingly abundant in citrus groves in central Arizona. The extremely painful stings of this wasp have caused laborers to refuse to work in infested groves and, in some cases, up to 20 per cent of the marketable fruit has remained unpicked for this reason. Some growers have used, with varying degrees of success, a common commercially available household spray containing as active ingredients 2 per cent chlordane, 0.115 per cent piperonyl butoxide and 0.046 per cent pyrethrins, plus small quantities of polymerized glyceryl cleate and piperonyl mercuric lactate. This spray is costly, and laborers in citrus groves have not been fully satisfied with its effectiveness, since the wasps are not always knocked down.

With an increasing number of complaints being registered, work was initiated in 1953 in an attempt to find an insecticide formulation that would satisfy two basic requirements: That is be inexpensive and that it give a rapid knockdown of the treated wasps. Other factors were considered of secondary importance.

BIOLOGY.—In certain citrus areas of Mexico, where it is believed this wasp may have originated, some groves have been abandoned because of high wasp infestations. In Arizona the principal infested area lies in the eastern part of the Salt River Valley near Phoenix.

The number of nests per tree was observed to vary from 1 to 26. In one grove where wasps were abundant a single tree contained 26 nests, 12 of which were active. Approximately 98 per cent of all nests observed were constructed on the east side of the tree, facing toward the trunk; a large percentage of these nests were in the northeast quadrant of the tree. Since the faces of the nests turned inward, general dusting or spraying as locally practiced for citrus thrips control does not eliminate the wasps, although it may tend to suppress them. The nests of this species are elongated and vertical, usually twice as long as wide, rather than like the more familiar circular, horizontal nests of other species of *Polistes*. Nests range from 6 to 14 inches in length and may be from 2 to 6 inches wide. The number of wasps per nest varies from less than 100 to more than 200.

On first observation this wasp appears to be a nervous, hostile insect. Any sudden external movement causes the entire worker force to face the movement and raise their wings in a belligerent attitude. It was observed, however, that they did not attack unless provoked. When the nest is disturbed, the wasps attack in number, inflicting very painful stings on the intruder.

Construction of the nest by the overwintering queen begins about the first of March. Usually she is helped by one or two other wasps, apparently overwintering workers. The material for the nest is usually taken from dead wood on the citrus trees, although cardboard also is frequently used. Eggs are placed in cells containing a small amount of a honey-like substance. After the second molt, the wasp larvae are fed larvae of various species of Lepidoptera by the workers. The caterpillars are usually skinned before they are offered. Upon maturing, the wasp larvae cover their cells by spinning a tough silken cap. The adults are completely formed in these cells and escape by cutting out the top.

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[2] Acknowledgment is made of the help of Mr. Lewis Whitworth, Assistant Maricopa County Agricultural Agent, in carrying out these tests.

Table 1.—Insecticidal control of adults of *Polistes exclamans* Viereck in citrus groves. Mesa, Arizona. 1953.

Formulation	Knockdown Rating[a]	Per Cent of "Knock Down" Wasps Dead in			
		1 Minute	1 Hour	3 Hours	8 Hours
Emulsion					
2% chlordane—2% thanite	3	64	79	94	100
1% chlordane—1% thanite	2	52	69	91	99
2% chlordane—0.25% allethrin	4	4	40	70	100
2% chlordane—0.125% allethrin	3	0	30	51	75
1% dieldrin—.25% allethrin	1	24	31	49	100
1% dieldrin—2% thanite	4	62	84	93	100
2% malathion	0	No knockdown			
2% malathion—1% thanite	4	10	50	84	100
Resilla oil					
2% chlordane—2% thanite	5	75	93	100	—
1% chlordane—1% thanite	5	71	87	99	100
Spray base oil					
1% thanite	5	79	93	100	—
3% thanite	5	78	94	100	—

[a] Ratings—0 to 5:
0=No knockdown; 1=30–44%; 2=45–59%; 3=60–74%; 4=75–89%; 5=90–100%.

CONTROL.—Twelve insecticide formulations, listed in tables 1 and 2, were tested against these wasps. Each formulation was applied to several nests in three or four areas with a 2-gallon hand compression sprayer. The sprayer was equipped with a hollow cone nozzle at the end of a 30-inch extension. This kept the applicator a safe distance from the nest. This precaution does not seem necessary, however, since in no instance was the author attacked while spraying the nests and wasps. The time required to knock down the adult wasps was recorded and the wasps were placed in cardboard cartons for later observations on mortality. Treated nests were tagged for later observation. Brood counts were made 1 week after spray application by examining several nests which received each treatment and counting the dead and living individuals. Observations were also made at this time to determine whether any of the treated nests had been reactivated.

The knockdown effectiveness of the 12 formulations was determined by noting the time required for the treated wasps to fall to the ground (Table 1). Thanite-oil solutions gave the quickest and most effective knockdown of any of the materials tested. For this test a deodorized kerosene spray base oil, weighing 6.6 pounds per gallon, was used. One and 3 per cent thanite formulations were very rapid in knockdown. The wasps dropped almost vertically from the nest when treated; in most instances large numbers could be gathered from the area directly beneath the nest. One per cent thanite in an oil solution exhibited no phytotoxic effects, but a 3 per cent thanite-oil solution very rapidly and severely injured foliage, fruit and small twigs of treated citrus trees.

Water emulsions of thanite in combination with chlordane or dieldrin were not as rapid as the oil solutions in knocking down wasps. Allethrin-chlordane emulsions appeared to be slightly faster in knockdown than either the chlordane-thanite or dieldrin-thanite emulsions. However, the time required for killing the knocked-down wasps was usually longer with allethrin-containing formulations than with the thanite-containing formulations. Chlordane-thanite formulations in Shell "Resilla" mineral oil (weight 7.1 pounds per gallon) gave good knockdown and rapid kill, but the treated areas of the citrus trees were severely injured, presumably more by the oil than by the insecticides. Two per cent malathion emulsion exhibited no knockdown of the wasps. Addition of 1 per cent thanite to the malathion formulation increased the knockdown effectiveness considerably.

Those formulations containing oil gave the most rapid kill of the knocked-down wasps, as shown in table 1. Emulsions containing allethrin were slowest. Emulsions of thanite-chlordane and thanite-dieldrin were about equal in time required to kill the wasps. Only two formulations required more than 8 hours for 100 per cent kill. These were 1 per cent chlordane-1 per cent thanite emulsion and 2 per cent chlordane-0.125 per cent allethrin emulsion.

Since the brood in an abandoned nest will die in 10 to 14 days from lack of care, the effect of the insecticides on the nest brood is of little importance except in the case of capped individuals. However, it was of some interest to determine the mortality of the developing stages following the insecticide treatments (Table 2). Oil-containing formulations exhibited the greatest effect on the brood, both capped and uncapped. Kill of larvae in open cells ranged from 16.6 per cent in the 1 per cent chlordane-1 per cent thanite emulsion-treated nests to 100 per cent for several of the other formulations. The 1 per cent dieldrin-2 per cent thanite emulsion and 1 per cent dieldrin-0.25 per cent allethrin emulsion were much less effective in killing the brood than were any of the other formulations, except the above-mentioned chlordane-thanite formulation. All formulations showed very effective control of the capped adults, with the exception of the 1 per cent dieldrin-2 per cent thanite and 1 per cent dieldrin-0.25 per cent allethrin emulsions. Capped adults appeared to be very susceptible at this stage and were easily killed. In cutting their way out of their cells they undoubtedly ingest a certain amount of the residual insecticide that may

Table 2.—Mortality of brood in nests of *Polistes exclamans* Viereck following insecticide applications. Mesa, Arizona. 1953.

Formulation	Per Cent Mortality of				
	Uncapped Larvae	Individuals in Capped Cells			
		Larvae	Pupae	Adults	Eggs
Emulsion					
2% chlordane—2% thanite	91.1	100.0	72.2	89.4	88.8
1% chlordane—1% thanite	16.6	35.2	36.3	65.3	00.0
2% chlordane—0.25% allethrin	96.0	85.2	81.2	100.0	41.6
2% chlordane—0.125% allethrin	85.3	75.9	85.4	95.6	72.9
1% dieldrin—0.25% allethrin	70.0	50.0	77.2	25.0	65.2
2% malathion	97.2	59.7	59.0	100.0	50.0
2% malathion—1% thanite	100.0	72.8	97.4	100.0	33.3
1% dieldrin—2% thanite	50.0	100.0	91.0	33.3	51.3
Resilla oil					
2% chlordane—2% thanite	99.4	100.0	100.0	100.0	33.2
1% chlordane—1% thanite	100.0	100.0	100.0	100.0	20.0
Spray base oil					
1% thanite	100.0	93.4	100.0	80.0	86.1
3% thanite	99.5	100.0	100.0	100.0	63.6

be present on the cappings. Pupae and capped larvae appeared to be affected to about the same degree. Both exhibited a high mortality from the treatments. Eggs suffered the least in treated nests. None of the formulations showed any high degree of effectiveness as an ovicide. This is of very little consequnece since newly hatched larvae will die if not tended by the workers. Of the approximately 100 nests treated, none was reactivated.

SUMMARY.—Twelve formulations of insecticide sprays were tested for effectiveness against the wasp, *Polistes exclamans* Viereck, in citrus groves in Arizona. Of these, 1 per cent thanite in deodorized kerosene spray base oil was the most effective and least expensive. This formulation gave a quick knockdown of the wasps and good control of the nest brood. During the fall of 1953, a large amount of this formulation was used very successfully by growers with no injury to the citrus trees. The nests sprayed with this formulation were not reactivated.

Tests with BHC Emulsion Sprays to Keep Boring Insects Out of Pine Logs in Massachusetts[1]

W. B. BECKER,[2] *Massachusetts Agricultural Experiment Station, Amherst*

Before DDT was developed as an insecticide, almost all spray materials that were reported effective in keeping borers out of unseasoned logs were dissolved in oils (Craighead 1922, Whitten 1942, Becker 1944, Atwood 1945, Connola *et al.* 1947, and others). Bess (1944) indicated that No. 2 fuel oil alone gave some protection against pine borers. Becker (1945, 1946) obtained data indicating that kerosene or No. 2 fuel oil alone, applied in large enough amounts to wet the bark thoroughly, effectively prevented elm bark beetles from breeding in elm logs. DDT, in oil, was also effective (Liming *et al.* 1948).

The present writer (1947) noted that DDT emulsifiable concentrates, diluted in water, also effectively prevented elm bark beetles from breeding in unseasoned elm logs and were more effective than DDT wettable powder sprays. DDT emulsion sprays also had a much longer residual effect than DDT wettable powder sprays in preventing elm bark beetles from feeding on twigs of living elms (Liming *et al.* 1948). Consequently when this study with pine borers was started in 1948 most attention was devoted to emulsifiable concentrates of various insecticides diluted in water. If effective, there could be advantages over diluting in oil with respect to expense, transporting spray materials in the woods, injury to living plants, fire hazards, etc.

Since the introduction of synthetic organic insecticides there have been reports of some success against insect pests of various unseasoned logs with DDT but results were sometimes erratic. More consistent success has been reported with BHC. Most reports emphasize results with these materials dissolved in oils but some discuss results with the emulsifiable liquids or wettable powders diluted in water, or discuss dust applications. (Balch 1946, Simpson 1947, Johnston & Kowal 1949, Kowal 1950, Kinghorn & Webb 1950, Johnston 1952, Blais 1953, Connola *et al.* 1953, and others).

EXPERIMENTAL PROCEDURE.—In this preliminary study, pine logs of cordwood size were used. The logs had been cut from living red or white pine trees during the winter. They were sprayed only once in the early spring before the insects' flight period, and then exposed to attack by borers until autumn.

Spraying Equipment.—Small compressed air, garden-type hydraulic sprayers were used. Adjustable spray nozzles could change the spray to any desired pattern from a broad cone to a solid stream.

Spraying Techniques.—If logs are not completely sprayed, insects may gain entrance without contacting any spray residue. In addition, there is apt to be much less uniformity in the amount of spray applied per square foot of bark in different tests if the application stops before the liquid begins to run off. Consequently, when spraying individual logs in these tests, the entire surface was sprayed until the liquid began to run off. Such thorough treatment necessitated handling and rolling each log. Immediately afterwards, the logs from each treatment were grouped together. In some years the groups were placed in a row; in other years they were scattered at random. The first year (1948), test logs were laid side by side in the sun, but in subsequent years they were piled in partial shade in stands of pines.

Each test group included 10 logs of cordwood size or equivalent. The individual logs within a group varied in diameter, but from group to group an attempt was made to have the diameters of the logs and the total bark areas comparable.

When spraying log piles *in situ*, 1 or 2 gallons of spray were directed as uniformly as possible to the top and all sides of stacks of equal size without inserting the spray nozzle into the pile. Each stack contained ½ cord (4 feet square) of logs. Spray coverage was excellent on the outside of the pile but probably not complete on bark surfaces within the pile. Therefore to avoid the possibility of insects from infested logs migrating to other logs in the same pile before contacting some spray residue, insect infested logs were carefully excluded when the logs were stacked. The piles were scattered at random in partial shade in stands of pines. This type of test was conducted to determine whether stacked logs can be satis-

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[2] The author is indebted to the Department of Forestry at the University of Massachusetts for providing the logs for this study at their Mount Toby Forest Reservation in Sunderland, Massachusetts.

factorily protected without the inconvenience of handling individual logs.

Method of Examining Logs.—The surface of the bark was examined periodically, usually once a week throughout the spring and summer, for signs of insect activity. In the autumn, the bark was removed and the insect tunnels in and on the wood classified and tallied. The sapwood was also cut into whenever necessary to identify a gallery. The data represent sampling 100 per cent of all logs and log piles in the study.

Insects Involved.—For the purposes of the test, insect damage was classified into four main groups: damage caused by (1) round-headed borers (Cerambycidae), (2) ambrosia beetles (Scolytidae), (3) bark weevils (Curculionidae), and (4) bark beetles (Scolytidae). It was not always practicable to separate the damage further. However, specimens of the insects were collected whenever possible. Some logs were caged later, and grubs were reared to adults. The genera and species in the different groups are listed below.[3]

1. Round-headed borers: Pine sawyers (*Monochamus* sp.) were the most damaging. The grubs dig large holes deep into the wood. *Asemum moestum* Hald. was also common in the wood. These two species probably form the basis for almost all the control figures for this group of insects. Other grubs found usually in the outer sapwood or in the bark included *Stenocerus lineatus* Oliv. and *Acanthocinus obsoletus* (Oliv.), species of *Pachyta*, *Leptura*, and *Leptostylus* or *Leiopus*.

2. Ambrosia beetles: *Gnathotrichus materiarius* (Fitch) dug deep into the wood, forming branched, black-stained galleries about 1/16 inch in diameter.

3. Bark weevils: *Pissodes approximatus* Hopk. was most abundant, but there were a few larvae in the genus *Hylobius*. The grubs dig short tunnels between the bark and wood but sometimes penetrate the outer sapwood just before they pupate.

4. Bark beetles: *Ips pini* Say, *Orthotomicus caelatus* (Eichh.), *Hylurgops pinifex* (Fitch), *Dendroctonus valens* Lec., and *Pityogenes hopkinsi* Sw. were collected in the bark of different logs. Sometimes the outer sapwood was penetrated for pupation purposes especially by *P. hopkinsi* Sw. digging in the thinner bark on some white pine logs.

Occasionally, flat-headed borer larvae (Buprestidae) were found in the bark or wood. They included *Chrysobothris* sp. and *Dicerca* sp. Larvae of the beetle, *Pytho americanus* Kby. (Pythidae), were quite common in bark infested by other borers.

RESULTS.—The percentage of control given for round-headed borers, ambrosia beetles, and bark weevils is based on the number of galleries per treatment; for bark beetles it is based on the percentage of bark area that was infested per treatment.

Spraying Individual Logs.—In early tests with DDT diluted in kerosene, 0.8 and 1.6 per cent DDT solutions

[3] Insects were identified by specialists in the Section of Insect Detection and Identification; Entomology Research Branch, Agr. Res. Serv., U.S.D.A.

Table 1.—Prevention of borer infestation by spraying pine logs[a] with BHC or lindane emulsifiable concentrates diluted in water. 1948, 1950, 1951, and 1952.

Gamma Isomer Content of Emulsions by Volume	Bark Area (Sq. Ft.)	Galleries in Wood: Roundheaded Borers No.	Roundheaded Borers Per Cent Control	Ambrosia Beetles No.	Ambrosia Beetles Per Cent Control	Galleries in Bark: Weevils (Pupal cells at Cambium) No.	Weevils Per Cent Control	Bark Beetles (Per Cent) Area Infested	Bark Beetles Control
				White Pine Logs, 1948					
BHC, 1.2%	40.3	0	100	0	—	0	—	0	100
0.6%	57.6	0	100	0	—	0	—	0	100
Unsprayed[b]	41.9	13	—	0	—	0	—	50.0	—
				Red Pine Logs, 1950					
BHC, 0.8%	45.0	0	100	0	100	0	100	0	100
0.4%	44.0	0	100	0	100	0	100	0	100
0.2%	45.0	0	100	0	100	0	100	0	100
0.1%	50.3	0	100	54	69	4	98	0	100
Unsprayed	44.0	60		172		193		81.2	
				White Pine Logs, 1951					
Lindane, 0.1%	56.5	2	95	2	91	68	93	0	100
0.05%	55.5	3	92	10	57	168	82	0	100
0.025%	56.6	10	73	10	57	325	66	0.74	98
Unsprayed	49.2	37		23		953		32.0	
				White Pine Logs, 1952					
BHC, 0.4%	55.5	0	100	0	100	0	100	0	100
0.2%	48.2	0	100	3	0	0	100	Trace	99+
0.1%	46.1	0	100	0	100	13	0	Trace	99+
0.05%	50.3	28	60	1	67	25	0	Trace	99+
0.025%	55.5	32	54	15	0	139	0	4.4	95
Unsprayed	37.7	70		3		13		87.9	

[a] Each treatment composed of 10 logs, of cordwood size or equivalent, sprayed individually.
[b] Six buprestid galleries were also present.

were not consistently effective against all types of pine boring insects. However, BHC, liquid concentrates diluted in kerosene to 1.2, 0.8, 0.6, 0.4, 0.2, and 0.1 per cent gamma isomer by volume gave 99 to 100 per cent protection against all types of borers in the single series of tests conducted in which 10 cordwood logs were sprayed per treatment.

In early screening tests with emulsifiable concentrates diluted in water to 0.8 per cent of active ingredient by volume, DDT, toxaphene, DDD, and methoxychlor were not effective against all types of pine borers. Similar results were obtained with 0.4 per cent chlordane and 1.6 and 0.8 per cent DDT in another series of tests. If would seem desirable to protect saw logs against all types of borers rather than just a few; so further studies were confined to BHC because it showed more promise in this respect.

In tests with BHC emulsifiable concentrates diluted in water to several different concentrations between 1.2 and 0.025 per cent gamma isomer by volume, complete protection of red or white pine logs was obtained with as little as 0.4 per cent gamma isomer and with one small exception with 0.2 per cent gamma isomer (Table 1). The single exception involved only three ambrosia beetle galleries plus a trace of bark beetle attack in one group of 10 logs. All applications from 0.4 to 0.025 per cent gamma isomer were repeated.

Spraying Piled Pine Logs in situ.—The following results are based on studies in two different years in which ½ cord (4 feet square) of logs was sprayed per treatment. The application of 2 gallons of an emulsion, diluted in water, containing approximately 0.4 per cent gamma isomer of BHC by volume per pile, gave 97 to 100 per cent reduction of infestation by round-headed borers and ambrosia beetles (both deep wood borers) and bark weevils (Table 2). It also reduced the area infested by bark beetles 91 to 98 per cent. One gallon sprayed at the same concentration gave 91 to 100 per cent reduction of wood borers and bark weevils. The bark beetle infested area was reduced 46 per cent one year and 95 to 99 plus per cent another.

The following results are based on one season's work. At 0.2 per cent gamma isomer content, 2 gallons to ½ cord gave 87 to 88 per cent reduction of round-headed borers, ambrosia beetles, and bark weevils and 77 per cent reduction of the area infested by bark beetles. This is still considerable reduction. One gallon at the same concentration gave 87, 50, 90, and 78 per cent reduction, re-

Table 2.—Prevention of borer infestation by spraying pine log piles[a] *in situ* with lindane emulsifiable concentrates diluted in water. 1951–1952.

Treatment[b]	No. of Logs and Back Area	Galleries in Wood: Roundheaded Borers No.	Roundheaded Borers Per Cent Control	Ambrosia Beetles No.	Ambrosia Beetles Per Cent Control	Galleries in Bark: Weevils (Pupal cells at Cambium) No.	Weevils Per Cent Control	Bark Beetles (Per Cent) Area Infested	Bark Beetles Control
Mostly red pine, a few white pine logs, 1951									
Two gallons									
0.4%	82 logs 382 sq. ft.	4	99	0	100	210	97	1.6	91
0.2%	100 logs 473 sq. ft.	76	87	4	88	772	88	4.1	77
0.1%	79 logs 384 sq. ft.	196	67	45	0	837	87	2.8	84
One gallon									
0.4%	104 logs 436 sq. ft.	28	95	2	94	560	91	9.7	46
0.2%	98 logs 404 sq. ft.	80	87	16	50	665	90	3.9	78
0.1%	92 logs 417 sq. ft.	265	56	48	0	1,235	81	7.1	60
Unsprayed	120 logs 485 sq. ft.	597		32		6,495		17.9	
Red pine logs, 1952									
Two gallons (0.4%)	124 logs 441 sq. ft.	1 1 shallow[c]	99+	1	99+	206	97	0.6	98
One gallon (0.4%)	117 logs 449 sq. ft.	17 5 shallow[c]	98	5	98	611	91	1.4	95
Unsprayed[d]	117 logs 468 sq. ft.	783 108 shallow[c] 1,110 tiny[c]		249		6,990		28.4	
White pine logs, 1952									
One gallon (0.4%)	134 logs 451 sq. ft.	6 8 shallow[c]	99+	0	100	223	97	0.1	99+

[a] Logs were of cord wood size and each pile was 4 feet square.
[b] Gallons per pile and gamma isomer content by volume.
[c] These are not included with other data because they represent very small species which, in the unsprayed check pile, were confined almost entirely to one log.
[d] Figures given are estimates for ½ cord because this untreated pile actually contained only 1/6 cord.

spectively, (Table 2). The only poor results here were obtained with the wood-boring ambrosia beetles.

A 0.1 per cent gamma isomer spray was generally much less effective for spraying log piles. Control of ambrosia beetles fell off quite abruptly in both the 1- and 2-gallon spray applications per pile. In this instance, the ambrosia beetles were more abundant in the sprayed piles than in the unsprayed check pile (Table 2).

Cost of the Spray.—At late 1952 prices, the cost of the BHC emulsion spray, after diluting with water to 0.4 per cent gamma isomer content, was about 12 cents a gallon; the 0.2 and the 0.1 per cent gamma isomer emulsion sprays were 6 and 3 cents, respectively. When spraying individual logs, 1 to 1½ gallons of a 0.2 per cent gamma isomer spray were needed with the equipment used, to wet 10 logs of cordwood size thoroughly and give complete protection. When spraying piled logs, 2 gallons of a 0.4 per cent gamma isomer spray were needed to give 91 to 100 per cent reduction of infestation in piles containing ½ cord of logs. This spraying of piled logs considerably reduced the quantity of spray needed and eliminated the labor of handling each log. If a BHC concentrate were diluted in oil, instead of water, the cost of the oil would have to be added.

PHYTOTOXICITY OF SPRAYS TO LIVING PLANTS.—To date, early spring dormant applications of emulsion sprays containing up to 0.4 per cent gamma isomer (by volume) have not visibly injured any needle-leaved evergreens or broad-leaved deciduous trees when applied directly to them by hydraulic sprayers. These sprays were diluted with water from commercial emulsifiable concentrates containing 11.7, 15, or 20 per cent gamma isomer of BHC. Sprayed plants included white and red pines, eastern hemlock, speckled alder, white ash, trembling aspen, basswood, gray, paper, and yellow birches, blueberry, choke cherry, American chestnut, alternate-leafed dogwood, wild grape, hazelnut, pignut hickory, red and sugar maples, pin, red, and white oaks, staghorn sumach, viburnum, and willow.

Applications during the growing season, however, have often injured the foliage of broad-leaved deciduous hardwoods, sometimes severely. Most damage usually occurred at 0.4 per cent, less at 0.2 per cent, and least at 0.1 per cent gamma isomer content when using any one commercial concentrate. At any one of these spray dilutions, less plant injury usually resulted when a 20 per cent gamma commercial concentrate was used than when an 11.7 per cent gamma commercial concentrate was used. This could be due to the smaller volume of solvent in the final spray when using the 20 per cent gamma concentrate, although different solvents may vary in their phytotoxic effects. So far, no needle-leaved evergreens have been visibly injured when these same sprays were applied during the growing season. Such plants include white pine, eastern hemlock, and a number of ornamental evergreens including spruces, junipers, firs, yews, arborvitae, and a few specimens in the genus *Chamaecyparis*. Lack of phytotoxicity would also be desirable in the event BHC sprays are applied to keep borers out of living trees that are weakened or exposed to epidemic numbers of borers after a hurricane or fire.

DISCUSSION.—Although these tests have given most promising results, additional studies will be conducted with large saw logs which may season less rapidly and be attractive to beetles over a longer period of time. Such logs might require a higher concentration of BHC in order to obtain the same protection. Any logs might require more BHC under more severe conditions of exposure to weathering or beetle attack. More work is also needed on the spraying of logs stacked in different ways. More work is needed on treating log piles that contain a few insect-infested logs because incomplete spray coverage inside the pile might permit beetles going directly to other logs within the pile without contacting any spray residue. In practice, an occasional insect-infested log may easily be unintentionally included with green, uninfested logs when stacking.

Because phytotoxicity may vary with factors other than those concerned with the insecticide itself, e.g., plant species and varieties, plant and leaf development, weather, etc., more information is needed on this subject.

SUMMARY.—In four different years under ordinary conditions of beetle attack in central Massachusetts, BHC or lindane emulsion sprays diluted in water were consistently good for keeping wood and bark boring beetles out of unseasoned pine logs. In two series of tests single applications of an emulsion containing 0.2 per cent gamma isomer gave almost complete protection all season long when applied to individual pine logs of cordwood size. At 0.4 per cent gamma isomer, protection was complete.

Spraying stacked cordwood carefully with 0.4 per cent gamma isomer emulsions also gave excellent protection against these pests when used at the rate of 2 gallons to a ½-cord pile. At 0.2 per cent gamma isomer content, the protection was somewhat less, but still good.

The highly effective 0.4 per cent gamma isomer spray emulsion caused no visible injury to living pines, hemlock, or deciduous plants when applied in the spring before new growth appeared. No injury has yet been noticed on a number of needle-leaved evergreens that were sprayed during their growing season. However, leaf injury often resulted, when broad-leaved deciduous hardwoods were sprayed when in foliage with 0.1, 0.2, or 0.4 per cent gamma isomer spray emulsions.

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Factors Affecting the Performance of Treadle Sprayers[1]

W. N. BRUCE and GEORGE C. DECKER[2]

Treadle sprayers developed for the spraying of cattle are by no means infallible or foolproof, but when properly installed and operated they provide one of the most efficient and economical means of obtaining effective control of flies, including tabanids, attacking cattle. The work of Bruce & Decker (1951) was received with enthusiasm by research workers and cattlemen alike. A number of entomologists initiated similar studies, and dairymen and ranchers in many parts of the country built or purchased and installed treadle sprayers on their farms. The results obtained were highly variable and the extremes ranged from phenomenal success to dismal failure. In checking the cause of failures it soon became apparent that much of the difficulty could be traced to faulty design or improper installation and adjustment of the sprayer equipment. However, observed variations in performance in cases where the equipment was not subject to serious criticism led the writers into a study of factors affecting performance.

PRELIMINARY TEST OF MATERIALS.—Since most of the early work in Illinois involved only one material (a well known and widely used synergized pyrethrin product), a comparison of a few somewhat similar formulations and other materials seemed to be the first logical step. Identical treadle sprayer units were set up in four small experimental pastures where conditions were, for all practical purposes, comparable, and 12 materials (listed in Table 1) were tested in a 4-day rotation sequence until four replicates of each were obtained. Tabanid counts on the animals which were treated and check animals were made at twice daily intervals and the percentage of repellency calculated. The results obtained are summarized in table 1. It will be noted that all of the materials tested gave a fairly high degree of tabanid control. There seemed to be little difference in the performance of the various formulations containing 1.0% pyrethrins, but allethrins were apparently less effective. It must be noted, however, that these tests were not designed to develop significant differences between highly effective materials. The performance of three chemically unrelated repellents, Crag fly repellent,[3] Thanite,[4] and Repellent R-326,[5] was also highly satisfactory.

Table 1.—Preliminary repellency tests of 12 quite distinctive fly spray formulations as applied with a treadle sprayer to protect beef cattle from *Tabanus sulcifrons*.

ACTIVE INGREDIENTS OF SPRAY	MEAN PER CENT REPELLENCY
10% piperonyl butoxide and 1.0% pyrethrins	92.6
10% sulfoxide and 1.0% pyrethrins	91.8
10% MGK 264 and 1.0% pyrethrins	92.8
25% MGK 264 and 1.0% pyrethrins	97.5
25% MGK 264 and 1.0% allethrins	78.7
10% MGK 264 and 1.0% allethrins	81.3
10% MGK 264 and 1.6% allethrins	91.4
10% MGK 264 and 2.0% allethrins	92.2
50% Crag fly repellent, 2.0% piperonyl butoxide, and 0.2% pyrethrins	94.3
50% Crag fly repellent	90.1
10% Thanite	92.1
10% Repellent R-326	96.9

COMPARISON OF SIX SPRAY CONCENTRATES ON BEEF CATTLE.—A Latin square sequence of treatments was used on six beef herds in adjacent pastures in which the spray materials were rotated through the six treadle sprayers and the per cent repellency calculated for each of the treatment periods as shown in table 2. In this experiment the six groups of beef animals were on similar pastures and in the same environment and also subject to the same over-all horse fly population. This provided a

[1] Accepted for publication November 12, 1954.
[2] Associate Entomologist and Entomologist, respectively, Illinois Natura History Survey, Urbana.
[3] Butoxypolypropylene glycol 800.
[4] Isobornyl thiocyanoacetate.
[5] Di-N-propyl isocinchomerate.

Table 2.—Results of tests where six spray materials were rotated through treadle sprayers used by six herds of beef cattle, expressed as per cent repellency based on the untreated herd and corrected for herd differences in fly susceptibility.

Herd No.	Insecticide Formulations[a]						Mean
	A	B	C	D	E	F	
1	94.6	93.2	88.9	80.0	90.1	81.4	88.0
2	100.0	100.0	88.4	87.9	92.3	100.0	94.8
3	98.4	96.9	96.6	90.0	92.7	96.9	95.3
4	100.0	100.0	90.1	84.5	84.3	91.6	91.8
5	98.0	100.0	100.0	83.0	90.5	89.9	93.6
6	97.2	98.0	92.9	85.2	92.7	94.5	93.4
Mean % repellency	98.0	98.0	92.8	85.1	90.4	92.4	92.8

L.S.D. at 5% = 4.788.
L.S.D. at 1% = 5.518.
[a] A—23.68% piperonyl butoxide and 0.59% pyrethrins.
B—11.8% piperonyl butoxide and 1.18% pyrethrins.
C—5.92% piperonyl butoxide and 1.18% pyrethrins.
D—1.18% pyrethrins.
E—11.84% dimethylcarbate and 1.18% pyrethrins.
F—11.84% dimethylcarbate and 2.00% allethrins.

convenient experimental arrangment for comparing different spray formulations. In these tests the animal routine was of minor importance, since the beef animals went through the treadle sprayer at will during the day, when the fly populations were the heaviest. A high degree of protection was obtained with all materials except the one which contained only pyrethrins (Herd D). Here the deviation from the mean was highly significant. In general the activated pyrethrins were most effective, and when the activator was omitted the effectiveness of the spray was significantly reduced. When the amount of pyrethrins was reduced by half and the amount of piperonyl butoxide doubled, there was no change in the effectiveness of the spray, but when the piperonyl butoxide content was cut in half the effectivenss of the spray was significantly reduced. The substitution of dimethyl carbate for piperonyl butoxide resulted in a significant loss of tabanid control.

It may be worthy of note that the old, original sprayer first used in 1950 was used on Herd 1, whereas newer, possibly improved and presumably identical units were used on Herds 2 to 6. The degree of tabanid control obtained with the old sprayer was significantly poorer than that obtained with the new units and thus the efficiency of the sprayer units used is established as an independent factor affecting performance.

ANIMAL ROUTINE VS. SPRAY MATERIALS.—For this experiment, five dairy herds were selected and treadle sprayers were installed to provide a series of distinctive and at the same time typical patterns of animal routine.

The treadle sprayer for Herd No. 1 was located in a lane between a large farm lot and the pasture, and the animals had free access to the sprayer during the day. Habitually, the animals would go to the pasture after milking in the early morning, return at about 10:00 A.M., and leave the lot at about 1:00 P.M. They would come in again about 4:00 P.M., and after milking in the evening they would once more go through the sprayer on their way to the pasture. Thus, these animals made on an average about three round trips through the treadle sprayer during the day, and it should be noted that these animals used the sprayer during the part of the day when the horse flies were the most active.

The treadle sprayer for Herd No. 2 was located between a rather small barn lot and a pasture with a good water supply. Because of this, the animals made only two round trips a day, once in the morning and once late in the afternoon. Thus, they received no treatment during the heat of the day when protection is most needed.

The setup for Herd No. 3 was like that for Herd No. 2. However, the cattle were turned into another pasture at night. Therefore, these animals made only one round trip daily or one pass through the treadle sprayer in the morning and another on the return trip late in the afternoon. The average protection for this herd was low and control was not considered satisfactory.

Herd No. 4, like Herd No. 1, had free access to the sprayer but the animals' passage through the treadle sprayer was variable. In general it appeared that the animals learned to use the sprayer at more frequent intervals as the season progressed.

Herd No. 5 was another one in which the animals had free access to the treadle sprayer, and when permitted to use it at will governed their treatment, in general, according to the temperature and the horse fly population.

Five repellent fly sprays were compared by rotating the materials used in the five treadle sprayers at weekly intervals of time. An index for the horse fly (*Tabanus sulcifrons* Macquart) population level for each herd was established by making daily fly counts on the animals for 2 weeks prior to the initiation of the tests. Daily tabanid population counts were made on two check herds to establish seasonal trends and the data thus obtained were used to adjust per cent repellency values obtained by comparing pre- and post-treatment counts for each test period. A summarization of the data developed in this study is presented in table 3.

In all cases where the animals made three round trips a day through the sprayer (Herds 7, 10, and 11) tabanid control was highly satisfactory. When animals were allowed only two round trips per day the reduction in tabanid control was highly significant and with only one round trip per day tabanid control was definitely unsatisfactory. It is apparent one can often forestall adverse animal routine by placing the treadle sprayer in the gateway to a pasture so that the animals have free access to the lot and the drinking tank during the day.

The use of Crag fly repellent seemed to add materially to the performance of the spray. The performance of all formulations containing this repellent was significantly

Table 3.—The effectiveness of treadle sprayers in controlling *Tabanus sulcifrons* on dairy cattle as influenced by animal routine.

Herd No.	Insecticide[a]					Mean Per Cent Repellency	Number of Applications per Day	Dosage as Ml. per Cow per Day
	G	H	I	J	K			
5	92.5	96.6	100.0	96.0	100.0	97.0	6	3.8
1	92.8	97.1	92.3	92.0	97.2	94.3	6	3.6
4	84.6	94.7	93.6	93.2	100.0	93.2	4 to 6	3.1
2	84.6	88.9	88.6	82.4	89.9	86.9	4	2.4
3	70.5	73.4	79.1	72.5	76.8	74.5	2	1.3
Mean	85.0	90.1	90.7	89.9	92.8			

L.S.D. at 5% = 4.208.
L.S.D. at 1% = 5.798.
[a] G—10% piperonyl butoxide and 1% pyrethrins.
H— 7% piperonyl butoxide, 0.7% pyrethrins, and 50% Crag fly repellent.
I — 7% piperonyl butoxide, 1.34% cyclethrins, and 50% Crag fly repellent.
J—7% sulfoxide, 0.7% pyrethrins, and 50% Crag fly repellent.
K— 7% sulfoxide, 1.34% cyclethrins, and 50% Crag fly repellent.

higher than that attained with the standard (10% piperonyl butoxide and 1% pyrethrins) mixture. While these experiments were not designed to develop significant differences between highly effective formulations, it appears that sulfoxide might be substituted for piperonyl butoxide and that at the two to one ratio used here cyclethrins could be substituted for pyrethrins.

ANIMAL ROUTINE VS. HORSE FLY CONTROL AND MILK PRODUCTION.—In another experiment four dairy herds for which daily milk production records were available were selected for a study on animal routine, horse fly control, and milk production. In this test three of the herds were treated and one was untreated. Herd No. 1 received six applications a day, or three round trips through the treadle sprayer during the day. Herd No. 2 received only two round trip applications a day but it obtained what would be considered a satisfactory degree of horse fly control; whereas, Herd No. 3, getting only one round trip application per day, had an unsatisfactory degree of horse fly control. Milk production data were taken for individual animals by the cooperating dairyman. The per cent reduction of *Tabanus sulcifrons* in each herd during the treatment period and the mean differences in milk production of 10 animals in each herd between the three-week base period and the three-week treatment period are given in pounds of milk per animal per day in table 4.

Analysis of the milk production data shows a mean significant difference at the 5 per cent level of 20.44 pounds of milk. There was a close correlation between per cent reduction in horse flies and milk production trends for the four herds studied. The correlation was significant at the 5 per cent level with a correlation coefficient of −0.977. Milk production figures indicate that animals which had three round trip treatments per day received a highly significant degree of protection from horse flies. The herd receiving two round trip treatments per day also had a highly significant degree of protection from horse flies in terms of milk production. The herd receiving only one round trip per day, although obtaining a significant degree of protection as reflected in milk production, was also significantly less productive than the herd receiving three round trip treatments per day. The three round trip treatments per day is rather typical of the animal routine established by beef cattle in the horse fly area. Thus, in general, a higher degree of horse fly control is attained by beef animals than by dairy animals because of the interference imposed upon normal dairy animal routine by the herd management.

Table 4.—The influence of animal routine upon the effectiveness of treadle sprayers in controlling *Tabanus sulcifrons* and the resulting deviations in milk production.

	Herd No.			
	1	2	3	4
Differences in milk production[a]	+20.6	+10.2	− 4.1	−39.01
Ave. number of horse flies 3 weeks before treatment	6.06	5.90	5.20	5.65
Ave. number of horse flies for 3-week treatment period	0.21	0.83	1.12	5.60
Per cent reduction of *T. sulcifrons* during treatment periods[b]	96.37	85.75	74.6	2.7
No. of treatments per day	6	4	2	0
Dosage as ml. per cow per day	3.6	2.4	1.2	0

[a] Between a 3-week base period and a 3-week treatment period, given as lbs. per animal. Mean difference for significance:
5% = 20.44 lbs. of milk.
1% = 27.60 lbs. of milk.

[b] Correlation between % repellency and difference in milk production is significant at the 5% level—R = −0.977
R Requires 5% = .950
1% = .990

OTHER CONSIDERATIONS IN INSTALLING AND OPERATING TREADLE SPRAYERS.—The breed of animal influences to a considerable extent animal acceptance of the treadle sprayer. It was found that the Brown Swiss cattle readily accepted the treadle sprayer. The Holstein was the next easiest animal to educate in the use of the treadle sprayer, followed by the Guernsey, Jersey, and lastly by the Ayrshire. The Ayrshire is a particularly excitable animal and in order to establish a treadle sprayer in their daily routine, it was found almost necessary to build the sprayer in stages at the place on the farm where it was to be put into operation. We have found that with excitable animals the chute can be made acceptable by building it over a period of 3 to 4 days. In such cases the animals should be allowed to go through the partially constructed chute for 2 or 3 days. After the animals become acquainted with the chute, the treadle and the spray unit can be put in place with the treadle depressed, which will allow the animal to go through the unit without being sprayed. When the treadle sprayer is put into operation 2 days later it usually will be fully accepted by even the most excitable animal in the herd. This procedure was used with at least two dairy herds in order to establish the sprayer as a part of the animals' daily routine. The beef animal herds which were used readily accepted the sprayer.

Another factor which was quite variable and difficult to evaluate was the herdsman. Some herdsmen were very impatient to see the treadle sprayer in operation and as soon as the sprayer was erected they attempted to drive the animals through it. Such a procedure retarded the animals' acceptance of the sprayer, and it is recommended that the animals should be allowed to accept a newly installed treadle sprayer instead of being driven through it.

SUMMARY AND CONCLUSION.—It is concluded from these tests that animal routine is a highly important factor in determining the efficacy of spray concentrates applied by a treadle sprayer. In fact, animal routine seems to be more important than the spray material itself, since it may mean the difference between treating the animal during the peak of horse fly abundance and hours in advance or after the peak of fly activity each day. It is concluded that for satisfactory or excellent horse fly control, the animals should be allowed free access to the treadle sprayer so that they may receive treatment during the part of the day when the horse fly population is highest. Animal routine significantly affected both the over-all repellency and the increments in milk production obtained by the application of repellent fly sprays.

The design and operation of the sprayer units and formulation of the insecticides used are also factors that materially affect the degree of tabanid control obtainable through the use of treadle sprayers.

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The Gypsy Moth Outbreak in Michigan[1]

W. V. O'Dell, *Plant Pest Control Branch, Agr. Res. Serv., U.S.D.A.*

The gypsy moth has been an unwelcome inhabitant of the Northeast since its introduction from Europe in 1869 at Medford, Massachusetts. During the first two decades of the current century, it became established throughout much of New England and in that time manifested itself to be a most persistent and destructive pest of forest, shade, fruit and ornamental trees. Currently, the generally infested territory includes most of New England and an extensive section of eastern New York, aggregating a total area of approximately 30 million acres. This represents less than 2 per cent of the total area of the United States.

Isolated infestations have been found occasionally at points well beyond the western limits of the generally infested region. In all such instances, intensive efforts have been made by cooperating Federal and State pest control agencies to obtain early eradication of these incipient outbreaks. The latest outbreak of this nature was discovered at Lansing, Michigan on May 19, 1954.

The infestation at Lansing was brought to the attention of pest control authorities as the result of a request for service directed to the City Forestry Department by a property owner. Swarms of small caterpillars were reported to be crawling over houses and devouring foliage of fruit trees and ornamentals at the southern edge of the city on Jolly Road. Specimens collected by personnel of the City Forestry Department were delivered to Professor Ray Hutson, Head of the Department of Entomology at Michigan State College, and to Mr. C. A. Boyer, Chief of the Bureau of Plant Industry, Michigan Department of Agriculture. After identification of specimens, these two men visited the collection site together to obtain firsthand information on the status of infestation. A brief examination at the collection site and environs showed that infestation was spread along Jolly Road for a considerable distance in either direction from the focal point originally reported. As a result of these observations, Mr. Boyer telephoned the U. S. Department of Agriculture at Washington and advised officials of the Plant Pest Control Branch, Agricultural Research Service, of the presence of gypsy moth infestation at Lansing and of the conditions observed. Mr. Boyer requested such assistance as could be provided by the Branch from its gypsy moth control project at Greenfield, Massachusetts in determining what action was needed to promptly exterminate this infestation.

Plans for Survey and Control.—The author was selected as the project representative to make an appraisal of infestation conditions at Lansing and to work with the Michigan Department of Agriculture in the planning and execution of survey and control operations that might be needed. A brief survey of the infested center and surrounding territory revealed that infestation had spread considerably from the point of probable introduction and could be found at scattered locations beyond this center by the simple process of making roadside observations from a slowly moving automobile. With this evidence that infestation might be rather widespread an immediate request was made to project headquarters for additional manpower to assist in delimiting the area of infestation.

During the afternoon of May 24, an emergency meeting attended by various City and State Department heads was held at the office of the Bureau of Plant Industry. Mr. Boyer and Professor Hutson advised the group concerning the discovery of gypsy moth infestation at Lansing. Represented at this meeting were the State Departments of Administration, Agriculture, Conservation, and Highways; the City Departments of Forestry and Recreation, and the Department of Entomology at Michigan State College. The seriousness of the situation was emphasized, particularly in relation to possible insect damage and imposition of Federal and State quarantines if infestation was not eradicated promptly. There was agreement that the presence of the gypsy moth in the Lansing area constituted a situation requiring emergency action. Agency representatives at the meeting pledged full support to the Michigan Department of Agriculture in the prosecution of a vigorous program of extermination. Since the appropriate season for applying effective controls was already well advanced, the need for swift, decisive action was apparent to all.

During the May 24 meeting, arrangements were made for officials in Administration and Agriculture to confer with Governor Williams and his staff on the following day. At the latter conference, the Governor was informed of developments to date and the need for legislative action to provide necessary funds for an immediate control program. At the conclusion of this meeting, the Governor authorized a special session of Michigan's "Little Legislature" to be convened on June 2 to consider a request for an appropriation to combat the gypsy moth. The "Little Legislature" is composed of members of the House Ways and Means Committee, the Senate Finance Committee, the Governor and Lieutenant Governor. It is authorized to meet in special session to appropriate funds, within specified limits, for emergencies that may arise when the full legislature is not in regular session. In this instance the call for a special legislative session did not specify the amount of funds to be requested, since additional survey work was expected to provide better information than was currently available relative to the magnitude of control operations that were needed.

The survey to delimit the infested area was conducted from May 25 to June 5, inclusive. Five project employees, assisted by an equal number of State and Federal agricultural workers from the Lansing area, made these examinations. Working out in all directions from the center of infestation, these men travelled in pairs and made observations of roadside growth from slowly moving vehicles. As infestation became less prevalent, spot examinations were made at frequent intervals in areas of favorable growth. Although this method of examination is not normally employed, under emergency conditions it can be used effectively in territory such as that in the Lansing area. Roads

[1] Presented at the meeting of the Eastern Branch of the Entomological Society of America held in New York, N. Y., Nov. 15–16, 1954. Accepted for publication Nov. 16, 1954.

in this area are located along the mapped section lines, laid out in 1-mile squares. Consequently, in many instances it was possible to make observations on all four sides of a mile square area. The survey was continued for at least 3 miles beyond the last evidence of infestation and the aggregate area covered amounted to 232 square miles.

At the beginning of survey work, arrangements were made with the Lansing Department of Forestry for use of a city-owned mist blower and an operating crew from that Department to spray all infested street and roadside trees that were located during the survey. Members of the City blower crew were deputized as employees of the Michigan Department of Agriculture to permit them to carry on spray work in township areas beyond the City limits. Survey crews reported to the City forestry headquarters at the end of each day's work to advise concerning new spots of infestation found during the day. By this procedure, mist-blower operations were kept abreast of survey work, with never more than 1 day of delay between discovery of infested roadside trees and their treatment by mist blower. The blower spraying was an important phase of the control program since it provided a means of preventing spread of gypsy moth caterpillars on the many automobiles and trucks that would be moving in and out of the infested area prior to the time that aircraft spraying could be started. An emulsion spray containing 1 pound of DDT per gallon was applied during these operations. Emulsifiable DDT concentrate required for this work was contributed by the Lansing City Forestry Department and the Federal Japanese Beetle Control Project at Detroit.

As the survey progressed, it became apparent that both the cities of Lansing and East Lansing should be completely sprayed by aircraft if all territory within the perimeter of infestation were to be treated as a single unit as desired. Plans for aerial spray operations were developed on the basis of daily survey results. By June 1, survey work had progressed to the point where only an occasional single egg mass was being found by the survey crews. With information then available, it was estimated that 58,000 gallons of insecticide would be required to aerially spray the infested area and a marginal safety zone. Since infested rural territory consisted largely of open agricultural lands, it was believed that such areas would require the use of less than ½ gallon of spray per acre in the aggregate. For spraying municipal areas, it was estimated that the normal application of 1 gallon per acre would be required over approximately all territory involved.

Since any action taken at the special legislative session to be held on June 2 would leave only about 2 weeks in which sprays could be effectively applied during the current larval season, Mr. Boyer and his staff proceeded to make provisional arrangements for conducting aerial spray operations. Bid invitations were issued to aerial spray operators for the purchase, handling and application of a DDT-oil spray solution containing 1 pound of technical grade DDT per gallon. Bids were to indicate the cost per gallon for this single package contract arrangement. Telephone and telegraphic bids were received to a specified deadline on May 28 and a provisional contract was then awarded to the Central Aircraft Company of Yakima, Washington on the basis of their bid being the lowest received. The invitations to bid had indicated an estimated minimum requirement of 40,000 gallons of spray solution and also specified that all municipal territory was to be sprayed by multi-motored aircraft.

Through Robert Ward, its operations manager, Central Aircraft took immediate action to be prepared for spray operations as soon as necessary funds were made available. Provisional contracts were arranged with two chemical companies for the purchase of DDT concentrates. Similar arrangements were made with a petroleum company in Lansing for receiving tank car shipments of concentrate, diluting and mixing the concentrate with kerosene, and delivery of the finished spray solution to airports in the Lansing area. Mr. Ward also arranged provisional contracts for the hire of a converted B-17 bomber with pilot and co-pilot for spraying municipal areas and three Stearman biplanes and pilots for spraying to be conducted in rural territory.

One phase of spray preparations made by the Michigan Department of Agriculture included written requests to authorities of each municipality involved for permission to conduct aerial spraying over city territory at an altitude of 200 feet above tree tops. At a scheduled meeting of the Lansing City Council on the evening of June 1, unanimous approval was given by council members to this request. In East Lansing, the City Manager obtained similar approval through individual phone calls to council members of that city. Written approval for low flying operations over these cities was required by the Civil Aeronautics Authority before a waiver of altitude requirements for the entire infested area could be granted.

At the legislative session convened in the State Capitol at Lansing on June 2, the request by the Michigan Department of Agriculture for emergency funds with which to combat the gypsy moth was given earnest consideration. After legislators had been advised relative to the history of the insect in the United States and to the methods now employed to control and prevent wholesale spread of the pest, Mr. Boyer was requested to present the information on which the appropriation request was being made. On the basis of bid quotations previously received, it was estimated that the application of 58,000 gallons of spray solution would cost approximately $77,000. Extensive surveys would be needed after July 1 to determine the possible presence of additional infestation in outlying areas. Spots of infestation that might be discovered as a result of these surveys would need to be sprayed in the spring of 1955. It was estimated that such survey and control operations would require approximately $73,000 in addition to the amount needed for the initial spraying program. After some discussion for the purpose of clarification of the issues involved, the Legislature voted unanimously to grant a special appropriation of $150,000 to be immediately available to the Bureau of Plant Industry, Michigan Department of Agriculture, for gypsy moth control and survey work through June 30, 1955.

PREPARATIONS FOR SPRAYING.—Immediately following the appropriation of special funds by the Legislature, the aerial spray contractor sent telegrams to secondary contractors calling for dispatch to Lansing of the materials, equipment and manpower needed to get spray operations

under way quickly. The Bureau of Plant Industry arranged with the State Police Commissioner for traffic controls during periods of spray application over main thoroughfares entering the cities of Lansing and East Lansing. Similar arrangements were made with the City Police Department in each municipality for slowing traffic during spray operations. Radio broadcasts were made to provide residents with details not covered in daily press releases and the Federal gypsy moth film in sound and color was projected by television station WKAR at East Lansing.

Spray planes arrived at Capitol City Airport on the morning of Saturday, June 5. The first tank car of DDT concentrate arrived on the afternoon of the same date. Each biplane pilot was assigned to a team of ground personnel and a specific area of spraying responsibility. The ground supervisor of each area accompanied his pilot, both by air and on the ground, to familiarize him with details of the area and to instruct him concerning the desirable progression of treatment. A similar reconnaissance was made by the pilot and co-pilot of the B-17 with the team of ground personnel to which they were assigned for spraying of municipal territory.

Final preparations for aircraft spraying were completed during the afternoon of Saturday, June 5. Because the period in which effective spray applications could be made was becoming extremely short, it seemed advisable to start operations on the following day. It was believed also that such spraying would cause less inconvenience to normal business operations in the city if the industrial and business districts of Lansing could be completed on Sunday when banks, stores and factories were closed. Before making a definite decision on the Sunday spraying, contacts were made with the Council of Churches and the Ministerial Association at Lansing and the situation explained. These groups approved the Sunday work under existing circumstances and expressed appreciation that they were consulted on the matter.

SPRAY OPERATIONS.—Aerial spray operations started at 5:00 A.M. on Sunday, June 6. The B-17 was based at Capitol City Airport and biplanes were based at a small, privately-owned airport in the southern edge of the city. The four-motored B-17 had a load capacity of 3,000 gallons of insecticide. In the work at Lansing, loads averaged from 2,200 to 2,400 gallons each; an amount sufficient for making two round-trip spray runs over a nine-mile strip of municipal and rural territory.

Insecticide was supplied to the B-17 from a 5,000 gallon storage tank by means of a stationary pump. The storage tank was kept supplied by means of tank-truck shuttle service between the airport and a petroleum plant 3 miles away. The B-17 was equipped with a quick-hitch device under the fuselage to which a 3-inch supply hose could be rapidly connected. The loading time averaged 8 to 10 minutes.

Biplanes were loaded directly from oil delivery trucks operated by the petroleum company having the insecticide mixing contract. Because of efficient pumping and metering equipment on these trucks, there was an average elapsed time of only 4 minutes between the landing and take-off of biplanes at each reloading with 100 gallons of insecticide.

On the first day of spraying the B-17 treated approximately three-fourths of the municipal area of Lansing, including all business and industrial areas. Exceptionally good weather conditions permitted spraying to be continued each morning and evening for five successive days; the program being completed at 8:00 P.M. on June 10. At the conclusion of the program, 59,022 gallons of insecticide had been sprayed on the tree and shrub growth within 86,400 acres of territory. The B-17 had applied 40,640 gallons of spray and the biplanes 18,382 gallons.

Throughout the period of spraying, samples were taken from each batch of insecticide delivered to airports. These were delivered to the chemical laboratory of the Michigan Department of Agriculture where formulation tests were conducted to determine DDT content by weight percentage. In samples tested, only slight variations from the 12% specification were noted.

COMPLETION OF PROGRAM.—It is significant that various cooperating agencies were able to coordinate their efforts in this emergency and to successfully complete a fast moving pest control operation of such magnitude in a period of about 3 weeks. Except for the wholehearted cooperation of each individual and agency concerned, the results would undoubtedly be less gratifying. Factors contributing to the remarkable success of the Michigan control program include (1) an excellent cooperative relationship between all agencies involved in the program, (2) vigorous and farsighted leadership at the head of plant pest control programs in the Michigan Department of Agriculture, (3) a flexible legislative and appropriations procedure in Michigan, (4) a well planned overall gypsy moth control program that is based on experience and designed to meet emergency situations of this nature, and (5) employment of a spray contractor having wide experience and operational know-how in the projection of large-scale aircraft spraying programs.

TRAP SURVEYS.—Following completion of spray operations, plans were developed for conducting a gypsy moth trap survey in the Lansing area during July and August. Twenty-five high school teachers and college students employed by the Bureau of Plant Industry erected and tended 5,000 gypsy moth traps throughout an area of 1,600,000 acres having the city of Lansing at the center of the trapped area. Excellent trap coverage was obtained by using an average of two traps for each square mile surveyed. The survey was jointly supervised by a newly appointed State Leader for gypsy moth control and a supervisor from the Federal Control Project.

As a result of the trapping program, male gypsy moths were recovered from four traps, all located to the west of the area previously sprayed. One moth was recovered from each of three attracting traps and 44 moths were recovered at the fourth trap. Examinations in the vicinity of the latter trap revealed the presence of infestation on an old apple tree. No egg masses were found in preliminary examinations conducted at the three other attracting trap sites, although intensive scouting to be conducted during fall and winter months may result in discovery of additional infestation. Extensive spray operations will be conducted in the vicinity of the four attracting trap sites in the spring of 1955. Trap surveys will be continued indefinitely until there is assurance that gypsy moth infestation in Michigan has been exterminated.

Response of Moths of the Pink Bollworm and Other Cotton Insects to Certain Ultraviolet and Visible Radiation[1]

PERRY A. GLICK, *Entomology Research Branch*, and JOE P. HOLLINGSWORTH, *Agricultural Engineering Research Branch, Agr. Res. Serv., U.S.D.A.*[2]

Recent investigations have shown that insects in general are attracted in great numbers to electric lamps emitting radiant energy in the near-ultraviolet and visible regions of the electromagnetic spectrum (Glick & Hollingsworth 1954).

Previous investigations of collections of the pink bollworm moth, *Pectinophora gossypiella* (Saund.), in light traps have been limited to traps equipped with black-light or mercury-vapor lamps. It was therefore important to determine whether there are other radiation sources that will attract not only the pink bollworm moth but other species of moths affecting cotton. In 1953 laboratory and field experiments were conducted at College Station, Texas, to determine the particular radiation source most attractive to these moths.

LABORATORY TESTS WITH PINK BOLLWORM MOTHS.—From January through March tests were made of 28 lamps or combinations of lamps by releasing the moths in a specially constructured test tunnel in a laboratory at Texas A. & M. College. This tunnel (Fig. 1) was made of ¼-inch plywood and was 30 by 30 inches by 24 feet. It was open at both ends, and the inner surface was coated with a flat black paint. An opening 2 inches in diameter was located in the top at the center of the tunnel for releasing the pink bollworm moths. A door near the center was used for the removal of inactive or dead moths. Electrocuter grids of 0.108-inch wire, spaced 9/32 inch center to center and operated at approximately 3000 volts, were placed at the ends of the tunnel, and completely covered them.

A single 15-watt black-light fluorescent lamp (G.E. F15T8/BL) was used at one end of the tunnel as a check, and the lamp under test at the opposite end. The test lamp was placed outside the tunnel approximately 3 inches from the grids, so that all moths coming within this distance were killed and were considered as having been attracted to that particular lamp. Black baffles 4 feet square placed at each end behind the lamps provided uniform backgrounds and shielded out stray lighting. The tunnel was located in a darkened room, which was maintained at approximately 90° F. and 40 to 60 per cent relative humidity.

Black-light fluorescent and black-light blue fluorescent (G.E. F15T8/BLB) lamps were used in various numbers to determine the effect of different intensities.

Pink bollworm moths were incubated from infested seed cotton in the room with the tunnel. Eight incubation cages with collecting jars or traps (Shiller 1946) were maintained to provide the necessary moths. Only moths that had emerged during the 24-hours before each test were used. The number ranged from 7 in the first test to 400 in some of the later ones.

In most of the tests the moths were released in the tunnel at about 5 P.M., and dead moths in the vicinity of the screen were counted the next morning between 8 and 9 o'clock. Checks on speed of response showed that

FIG. 1.—Tunnel used in laboratory for studying the response of the pink bollworm and other moths to certain ultraviolet and visible radiation. An electric grid and test lamp are seen at end of tunnel.

over 50 per cent of the moths responding were attracted to the lamps within 5 minutes after their release. The ratio of attractiveness was determined from the number of moths attracted to the test lamp divided by the number attracted to the check lamp. Results of tests with the different sources of radiation are shown in table 1.

The only single lamp that attracted more pink bollworm moths than the check lamp was the spot-type mercury-vapor lamp (G.E. H-100-SP4), when provided with a special black-light transmitting filter (Kopp Glass Co., No. FR5860). Black-light blue lamps became less effective after several hours' use.

It was found in one experiment that three black-light and three black-light blue lamps were of equal attractiveness. Two black-light lamps proved to be nearly three times as attractive as a single black-light lamp, and more attractive than three such lamps. Three black-light blue lamps showed a greater attractiveness ratio than three black-light lamps.

The percentage of moths not attracted to either the check or the test lamp ranged from 4 for the white fluorescent to 44 for the SP4 mercury-vapor lamp with the filter.

There was little difference in the numbers of male and female moths responding to the black-light and black-light blue fluorescent lamps, as shown in table 2. The SP4 mercury-vapor lamp without a filter attracted a higher percentage of females. Fewer males responded to the RS Sunlamp and the Argon Glow (AR-1) lamp.

The results of these tests indicate that the check lamp

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[2] In cooperation with the Texas Agricultural Experiment Station.

Table 1.—Response of pink bollworm moths to various sources of radiation in laboratory tests.

Test Lamp[a]	Number of Lamps	Emitted Peak (Angstroms)		Number of Tests	Per Cent of Moths Attracted to—		Attractiveness Ratio
		Ultra-violet	Visible		Test Lamp	Check Lamp	
Mercury-vapor:							
Ozone 4	4	1,849	4,358	2	8	60	0.13
Germicidal 15	1	2,537	4,358	1	4	80	0.05
Sunlamp RS 275	1	3,654	5,780	2	23	63	0.36
Black-light:							
BH4 100	1	3,654	4,058	3	27	61	0.44
SP4 100 (with filter)	1	3,654	7,500	4	30	26	1.15
SP4 100 (without filter)	1	3,654	5,461	2	13	76	0.17
General lighting AH4 100	1	3,654	5,461	3	27	56	0.48
Glow:							
Argon (AR-1) 2	1	3,654	7,500	3	40	46	0.87
Neon (NE34) 2	1	—	6,400	2	22	42	0.52
Fluorescent:							
Sunlamp 20	1	3,131	5,780	3	26	47	0.55
Black-light 15	2	3,500	4,358	3	58	20	2.90
	3	3,500	4,358	5	55	27	2.04
	4	3,500	4,358	2	47	32	1.47
Black-light blue 15:							
New	1	3,500	4,058	4	46	36	1.28
	3	3,500	4,058	1	62	19	3.26
Old	1	3,500	4,058	3	36	51	0.71
Blue 15	1	3,654	4,358	2	9	70	0.13
Green 15	1	3,654	5,461	1	5	85	0.06
Gold 15	1	—	5,780	2	8	76	0.11
Pink 15	1	—	6,150	1	4	91	0.04
Red 15	1	—	6,400	2	13	67	0.19
Daylight 15	1	3,654	5,800	1	16	60	0.27
White 15	1	3,654	5,900	1	6	90	0.07
Standard cool white 15	1	3,654	5,850	1	12	80	0.15
Clear 15	1	3,654	4,358	1	7	76	0.09
Incandescent:							
Standard 15	1	3,800	10,000	1	6	84	0.07
30	1	3,800	10,000	1	4	89	0.05
Drying (R-40) 250	1	3,800	12,000	1	2	93	0.02
No lamp in test end	—	—	—	3	28	60	0.47

[a] Figures indicate wattage.

Table 2.—Sex ratio of pink bollworm moths responding to various sources of radiation.

Test Lamp[a]	Number of Lamps	Number of Moths Tested		Per Cent of Moths Responding to—			
				Check Lamp		Test Lamp	
		Male	Female	Male	Female	Male	Female
Mercury-vapor:							
Sunlamp RS 275	1	24	36	79	69	21	31
Black-light:							
SP4 100 (with filter)	1	53	47	38	48	62	52
SP4 100 (without filter)	1	23	33	91	82	9	18
Glow:							
Argon (AR-1) 2	1	145	80	59	45	41	55
Fluorescent:							
Black-light 15	2	85	85	22	29	78	71
	3	210	121	30	28	70	72
	4	153	113	40	41	60	59
Black-light blue 15:							
New	1	73	57	54	40	46	60
	3	184	130	26	21	74	79
Old	1	38	18	34	13	66	67

[a] Figures indicate wattage.

is the most efficient radiation source for attracting pink bollworm moths. This lamp produces radiation peaked at 3,500 angstroms. The optimum intensity of this radiation was attained with two of these lamps. Apparently no lamp completely repelled the moths. The longer wave lengths produced by the incandescent, white fluorescent, and drying lamps significantly increased the percentage of moths responding to the lamp. This increase might indicate that the moths were trying to avoid this radiation by going to the check end of the tunnel.

LABORATORY TESTS WITH MOTHS OF OTHER COTTON INSECTS.—In the tests with moths of other species infesting cotton, the same equipment was used as for the pink bollworm moth. From May 23 to September 19, 89 lamps or combinations of lamps were tested. The peak of ultraviolet radiation ranged from 2,537 to 3,654 angstroms. In tests of various light intensities, from one to four 15-watt black-light fluorescent lamps and 15, 100, and 300-watt incandescent lamps were compared with a single check lamp.

Owing to the variation in the number of species of moths available from time to time, each species was not tested with all types of lamps. The various lamps and their respective energy radiation peaks used in tests with the bollworm, *Heliothis armigera* (Hbn.), are given in table 3. This insect showed the greatest response to the SP4 mercury-vapor lamp with the filter. Six per cent more male than female moths were attracted to this lamp, but the same lamp without a filter attracted 36 per cent more males.

The fall armyworm, *Laphygma frugiperda* (J. E. Smith), showed a much greater response to the mercury-vapor SP4 lamp without the filter than to the one with the filter. With the filter it had an attractiveness ratio of 9.5. The RS Sunlamp was also more attractive than the check lamp (attractiveness ratio 2.95).

The cotton leafworm, *Alabama argillacea* (Hbn.), showed a decided response to the SP4 mercury-vapor lamp without the filter, as the attractiveness ratio was 15.4. There were 50 per cent more females than males responding to the test lamp. With the filter the attractiveness ratio was 2.78, and 20 per cent more females responded to the test lamp.

The cabbage looper, *Trichoplusia ni* (Hbn.), was not available in sufficient numbers for tests of all the lamps. Of the lamps tested, it showed the greatest response to the RS Sunlamp.

The garden webworm, *Loxostege similalis* (Guen.), also showed a decided preference for the RS Sunlamp, responding at a ratio of 6.07. The SP4 mercury-vapor lamp was not tested with this moth.

All the moths used in the tests responded in greater numbers to ultraviolet radiation of high intensity than to that of low intensity. All the lamps that proved to be highly attractive to the moths radiate strongly in the ultraviolet region. They also have a relatively low ratio

Table 3.—Response of bollworm moths to various sources of radiation in laboratory tests.

Test Lamp[a]	Number of		Moths Attracted to—				Attractiveness Ratio
			Check Lamp		Test Lamp		
	Lamps	Tests	Number	Per Cent	Number	Per Cent	
Mercury-vapor:							
Ozone 4	4	1	156	91.8	14	8.2	0.09
Germicidal 15	1	4	446	98.0	9	2.0	0.02
Sunlamp RS 275	1	3	40	35.7	72	64.3	1.80
Black-light:							
BH4 100	1	2	47	78.4	13	21.6	0.28
SP4 100 (with filter)	1	4	116	20.6	447	79.4	3.85
SP4 100 (without filter)	1	4	93	29.5	222	70.5	2.39
General lighting AH4 100	1	2	100	69.9	43	30.1	0.43
Glow:							
Argon (AR-1) 2	1	2	95	100.0	0	0	0
Fluorescent:							
Sunlamp 20	1	6	314	67.2	153	32.8	0.49
Black-light 15[b]	1	1	76	41.5	107	58.5	1.41
	2	3	167	35.6	303	64.4	1.81
	3	2	47	21.4	173	78.6	3.67
	4	1	32	21.9	114	78.1	3.57
Black-light blue 15	1	3	223	69.0	100	31.0	0.45
Blue 15	1	2	27	100.0	0	0	0
Green 15	1	4	143	100.0	0	0	0
Gold 15	1	3	191	100.0	0	0	0
Daylight 15	1	2	230	97.9	5	2.1	0.02
White 15	1	2	153	100.0	0	0	0
Clear 15	1	2	208	100.0	0	0	0
Incandescent:							
Standard 15	1	1	129	100.0	0	0	0
100	1	1	114	100.0	0	0	0
300	1	1	123	84.8	22	15.2	0.18

[a] For emitted peaks see table 1. Figures indicate wattage.
[b] Lamps mounted in detection-type pink bollworm trap.

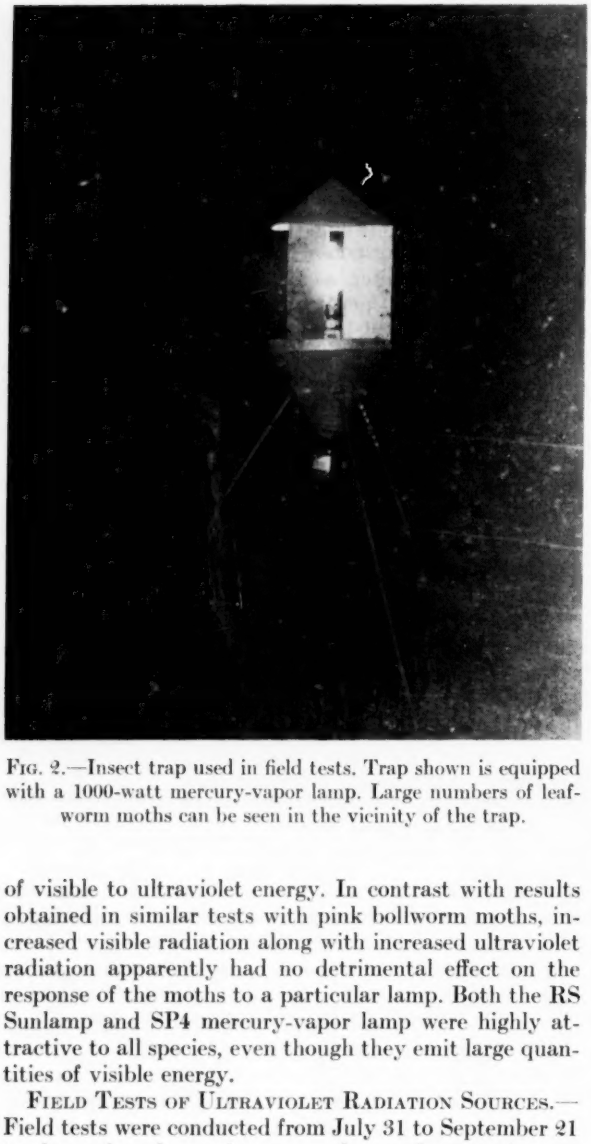

FIG. 2.—Insect trap used in field tests. Trap shown is equipped with a 1000-watt mercury-vapor lamp. Large numbers of leafworm moths can be seen in the vicinity of the trap.

of visible to ultraviolet energy. In contrast with results obtained in similar tests with pink bollworm moths, increased visible radiation along with increased ultraviolet radiation apparently had no detrimental effect on the response of the moths to a particular lamp. Both the RS Sunlamp and SP4 mercury-vapor lamp were highly attractive to all species, even though they emit large quantities of visible energy.

FIELD TESTS OF ULTRAVIOLET RADIATION SOURCES.—Field tests were conducted from July 31 to September 21 to determine the optimum number and type of near-ultraviolet lamps for use in insect-collecting traps. Comparison was made of 15-watt black-light and black-light blue fluorescent lamps. The traps (Fig. 2) were equipped for utilizing from one to four lamps in the center of a three-vaned baffle assembly. The funnels were provided with deflecting cones and drain devices to prevent moisture from entering the 1-gallon cyanide collecting jars. The traps were made of galvanized sheet metal and were supported by three legs made of tubular steel. Three traps were used for the entire test period, and on August 18 a fourth trap was installed. The traps were installed at 500-foot intervals along the east side of a 20-acre cotton field. In order to eliminate trap position as a factor in influencing catches of insects, the lamps were rotated from one trap to another each day during the tests. A statistical analysis was made of the catches of species for which complete data were recorded for at least 5 days.

In tests with different numbers of black-light lamps (Table 4), only the Diptera showed a significant difference in response due to the number of lamps. They showed the greatest response to traps equipped with three lamps. When different numbers of black-light blue lamps and a single black-light lamp were compared, only the cabbage looper responded differently. Traps equipped with three black-light blue lamps caught significantly greater numbers of this species than traps equipped with either one or two of these lamps (Table 5). The single black-light lamp was second in attractiveness; however, it also caught significantly greater numbers of this species than the single black-light blue lamp. In tests comparing different numbers of black-light blue and four black-light lamps (Table 6), the miscellaneous species of Lepidoptera

Table 4.—Insects caught in light traps equipped with different numbers of black-light lamps, July 31 to September 21, 1953.

INSECT	AVERAGE NUMBER CAUGHT PER NIGHT	PER CENT IN TRAPS WITH—		
		1 Lamp	2 Lamps	3 Lamps
Lepidoptera:				
Cabbage looper	349	25.2	35.5	39.3
Fall armyworm	528	29.6	39.4	31.0
Garden webworm	3,173	22.2	36.6	41.2
Bollworm	2,456	28.2	35.1	36.7
Miscellaneous	2,191	36.3	38.1	25.6
Coleoptera	45,700	43.2	24.6	32.2
Hemiptera	9,202	55.6	11.7	32.7
Homoptera:				
Cicadellidae	864	16.7	40.7	42.6
Ephemeridae	1,112	43.5	24.0	32.5
Trichoptera	13,150	26.8	47.6	25.6
Hymenoptera	1,080	17.3	59.7	23.0
Diptera	1,605[a]	22.9	24.6	52.5
Orthoptera:				
Crickets	123	30.3	41.6	28.1
All insects	81,533	40.2	30.4	29.4

[a] Significant difference. A difference of 24 per cent is required for significance at odds of 19:1.

Table 5.—Insects caught in light traps equipped with different numbers of black-light blue lamps and a single black-light lamp, August 18 to September 10, 1953.

INSECT	AVERAGE NUMBER CAUGHT PER NIGHT	PER CENT IN TRAPS WITH—			
		Black-Light Blue Lamps			Single Black-Light Lamp
		1 Lamp	2 Lamps	3 Lamps	
Lepidoptera:					
Cabbage looper	641[a]	13.2	22.9	36.5	27.4
Fall armyworm	867	15.6	19.5	38.9	26.0
Bollworm	1,474	15.7	30.0	35.0	19.3
Cotton leafworm	893	33.7	25.7	18.8	21.8
Miscellaneous	5,336	21.3	33.6	23.0	22.1
Coleoptera:					
Blister beetles	534	15.6	29.6	33.7	21.1
Miscellaneous	42,637	24.4	25.1	23.0	27.5
Hemiptera	22,855	8.8	25.6	30.0	35.6
Homoptera:					
Cicadellidae	4,725	22.9	26.2	21.0	29.0
Trichoptera	1,423	24.4	22.2	25.4	28.0
Hymenoptera	7,135	9.9	16.1	24.6	39.4
Diptera	7,210	15.1	21.1	28.1	35.3
All insects	95,730	18.4	24.8	26.3	30.5

[a] Significant difference. A difference of 12.6 per cent is required for significance at odds of 19:1.

Table 6.—Insects caught in light traps equipped with different numbers of black-light blue lamps and four black-light lamps, September 11–17, 1953.

Insect	Average Number Caught per Night	Per Cent in Traps with—			
		Black-Light Blue Lamps			4 Black-Light Lamps
		1 Lamp	3 Lamps	4 Lamps	
Lepidoptera:					
Cabbage looper	1,452	19.1	23.4	22.8	34.7
Fall armyworm	1,262	19.9	22.5	25.5	32.1
Bollworm	1,726	11.6	9.9	15.1	63.4
Cotton leafworm	4,462	12.4	22.4	39.2	26.0
Tomato hornworm	14	14.3	12.5	33.9	39.3
Tobacco hornworm	13	31.6	18.4	23.7	26.3
Miscellaneous	21,771[a]	16.8	21.6	22.2	39.4
Coleoptera:					
Blister beetles	1,015	24.4	24.4	25.0	26.2
Miscellaneous	51,740	19.5	28.7	29.9	21.9
Hemiptera:					
Cotton fleahopper	7,611	8.3	10.9	49.3	31.5
Miscellaneous	21,358	14.5	27.7	27.2	30.2
Homoptera:					
Cicadellidae	21,028	9.5	21.2	20.7	48.6
Trichoptera	6,340	19.6	21.8	28.4	30.2
Diptera:					
Syrphidae	2,080	21.5	13.9	22.3	42.3
Miscellaneous	20,492	20.2	34.6	21.1	24.1
Orthoptera:					
Crickets	208	12.8	23.0	30.8	33.4
All insects	162,572	16.5	25.6	26.9	31.0

[a] Significant difference. A difference of 16 per cent is required for significance at odds of 19:1.

showed a significantly greater response to the traps equipped with four black-light lamps.

CONCLUSION.—The results of these investigations indicate that the single 15-watt black-light fluorescent lamp is the most efficient light source for collecting moths of cotton insects in traps of the type tested. The black-light blue fluorescent lamp was nearly as efficient in most tests.

SUMMARY.—Laboratory tests were conducted at College Station, Texas, in 1953 with 23 sources of radiation to determine their attractiveness to the pink bollworm moth, *Pectinophora gossypiella* (Saund.). A mercury-vapor lamp with a black-light transmitting filter, and black-light fluorescent lamps without and with an integral filter (black-light blue) attracted the most moths. The principal radiation from these lamps is in the near-ultraviolet region of the electromagnetic spectrum. Lamps with their principal radiation in the visible portion of the spectrum attracted few moths.

There was little difference in the numbers of male and female moths responding to the black-light fluorescent and black-light blue fluorescent lamps. Five other species of moths infesting cotton were found to be highly responsive to near-ultraviolet radiation sources. The mercury-vapor lamps (with and without black-light transmitting filter), a spot-type Sunlamp, and the fluorescent black-light caused the greatest response.

In field tests to determine the optimum number and type of near-ultraviolet lamps for use in insect-collecting traps, a single 15-watt black-light fluorescent lamp was the most efficient.

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Control of the Two-Spotted Spider Mite on Bush Beans[1]

SATORU TOGASHI[2] and RALPH L. PARKER, *Kansas State College, Manhattan*

In Kansas, the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, has caused considerable damage to various plants for many years. Parker (1944) reported that this pest occurs in sufficient numbers to cause serious damage to bean plants in Kansas. The two-spotted spider mite has developed to a pest of prime importance in deciduous orchards and on other farm crops sprayed with DDT. Michelbacker *et al.* (1952) and Wingo & Thomas (1948) reported that this increase in mite populations is caused by the reduction of the predators. Parker (1944), Neiswander *et al.* (1950), and Reynolds *et al.* (1952) used various chemicals to control this mite.

PROCEDURE AND RESULTS.—The original source of mites was obtained from leaves of field bindweed, *Convolvulus arvensis*, which were heavily infested. Stock cultures were reared on bush beans grown in wooden greenhouse flats. An undetermined number of mites were transferred from infested bush bean leaves to uninfested bean plants by using a camel's-hair brush, 2 inches in width. The mites were brushed from the underside of the infested leaves to the upper surface of the leaves of the tests plants. Within a short time they migrated to the underside of the leaves of the newly infested test plants, the preferred area. The mites were introduced to the test plants when they had 10 to 12 fully expanded leaves. The acaricides were applied when the stage of growth of the plants averaged 24 to 26 mature leaves per plant to obtain leaf samples and high mite counts. Test plants were protected by tangle-foot bands and wirescreen cages to prevent migration of mites and invasion of injurious insects from nearby plants.

Six wettable powders and one emulsifiable liquid acaricide were used on Wade, Burpee, and Green Stringless Pod bush beans grown in pots and small beds. The sprays were applied to the test plants with a small 3-gallon compression hand sprayer. A shield was used behind and beside each plant to keep the spray from drifting.

Siegler (1947) and Reynolds *et al.* (1952) used portions of leaves for sampling. Reynolds' *et al.* (1952) use of a 7/8-inch diameter cork punch to cut out leaf discs was

[1] Contribution No. 632 Department of Entomology, Kansas Agricultural Experiment Station, Manhattan. Accepted for publication November 26, 1954.

[2] Former graduate student in the Department of Entomology, now employed by the California Packing Corporation, Merced. An adaptation of a thesis for the degree of Master of Science.

followed. The disc had a 0.6 square inch area and population counts were made from such discs cut from the bean leaves. Three discs were taken from each of 3 leaflets of the potted test plants of 6 replicates during each test. The sample was taken from the basal portion of the bean leaflet where mite populations were generally heaviest. From the beds of beans, 10 leaflets per bed were used for sampling. Three discs were punched out from the basal, middle, and apical part of each leaflet sample in the bed tests. Direct counts of the mites were made immediately under a wide-field binocular microscope; all living stages except eggs were counted. If the mites were in the quiescent stage, which precedes each molting period, they were probed with a dissecting needle and if they showed any signs of movement they were counted as living mites.

Wettable powders were used in these tests, 2 pounds per 100 gallons of water. Emulsion was used, 1 tablespoon per gallon of water. Only one spray application was made in each case.

ARAMITE.[3]—During the course of these experiments at the insectary, no injury was noted on bean plants sprayed with this chemical. Green Stringless Pod bush beans, grown in beds, were treated at the rate of 2 pounds of 15% aramite wettable powder per 100 gallons of water August 5, 1953, at 2:15 P.M. Twenty-four hours later a survival count showed a poor kill (Table 1), probably because of heavy rains. August 8 a large kill was obtained following the renewed spray August 7 as indicated by a survival rate of 2 per cent compared with the prespray counts. This rate of mite control remained high through the closing of this experiment on August 24, 1953, the final survival rate being 1 per cent or 99 per cent control.

In early September, Aramite was applied to Wade bush beans grown in pots. The initial kill was low but as the days progressed the long term residual value of the acaricide was evident (Table 1). The final counts of the 6 untreated plants totalled 1,489 mites compared with 91 on 6 of the sprayed plants, a 94 per cent control.

MALATHION.[4]—Green Stringless Pod beans in adjacent beds of plants sprayed with Aramite, Ovotran and the untreated plot, when sprayed with 25% malathion wettable power were believed to show a slight phytotoxicity as evidenced by a few leaves with signs of yellowing. Malathion was first used on Green Stringless Pod bush beans grown in beds at the same time as Aramite and

[3] Supplied by U. S. Rubber Co., Naugatuck Chemical, Naugatuck, Conn.
[4] Supplied by American Cyanamid Co., New York, N. Y.

Table 1.—Effects of acaricides[a] on two-spotted spider mites infesting bush beans.

	Results of Mite Counts on Dates Indicated							
	8/4	8/8		8/11		8/24[e]		
Treatment	PS[b]	NA[c]	S[d]	NA	S	NA	S	C[f]
15% Aramite	1,138	23	2	3	0.3	10	1	99[g]
25% malathion	1,501	88	6	318	21	1,475	98	14
50% Ovotran	1,861	228	12	52	3	2	0.1	99.9
Untreated	1,351	821	60	575	43	1,706	126	—
	8/12	8/14		8/17		8/22		
25% malathion	320	2	1	104	32	34	11	91[h]
57% malathion emul.	357	29	8	43	21	48	12	88
Untreated	441	544	123	638	145	389	88	—
	8/20	8/22		8/25		8/30		
50% Ovotran	351	321	91	198	56	287	82	89[i]
EPN 300	301	164	54	197	65	386	128	85
Untreated	362	486	134	575	159	2,154	694	—
	9/6	9/8		9/11		9/16		
15% Aramite	850	291	34	32	4	91	11	94[i]
50% Ovotran	576	335	58	48	8	34	6	98
25% Chlorobenzilate	577	92	16	11	19	84	15	95
Untreated	618	582	94	571	92	1,489	241	—
	9/7	9/9		9/12		9/17		
25% Diazinon	730	0	0	46	6	356	49	30[i]
Untreated	556	1,010	182	674	121	509	92	—

[a] Applied at 2 pounds of wettable powder per 100 gallons except the malathion emulsion was applied at the rate of 1 tablespoonful per gallon of water.
[b] Before spraying.
[c] Number alive.
[d] Per cent survival.
[e] Another count made on August 16 gave the following results: Aramite, NA-17, S-2; malathion, NA-249, S-17; Ovotran, NA-14, S-1; untreated, NA-601, S-45.
[f] Per cent control.
[g] Per 3 standardized leaf disc samples per 10 leaves.
[h] Per 3 standardized leaf disc samples per plant replicated three times.
[i] Per 3 standardized leaf disc samples per plant replicated six times.

Ovotran (Table 1), with expected poor results because of heavy rains. The 24-hour survival rate after the second application (August 7) was 6 per cent, based upon a comparison with prespray counts. While making population counts on the leaf disc samples from the malathion plot, it was noted that the majority of the mite eggs appeared viable. This was evident when the counts after 3 days showed a rapid increase in the number of live mites. They were mostly in the larval stages, and must have hatched after the treatment was applied. As the season progressed, a rapid increase in mites, which continued to the closing of the experiment August 24, 1953, was noted in this plot. The final counts totalled 1,475 mites in the treated bed and 1,706 in the untreated bed (Table 1).

The second experiment was done on Wade bush beans grown in pots, with excellent initial kill (1 per cent survival) but with a 32 per cent survival 4 days after the application (Table 1). This dropped to 11 per cent survival 9 days after the application.

OVOTRAN.[5]—Fifty per cent Ovotran wettable powder was first used on Green Stringless Pod bush beans in a bed. This experiment coincided with applications of 15% Aramite and 25% malathion (Table 1). The first application of Ovotran was ineffective because of heavy rain. A second 24-hour survival count, following a repeated application, resulted in a 12 per cent survival. The majority of the eggs appeared nonviable. Many of the adults, after being exposed to the spray residue for 24 hours, showed some activity. Live mite counts on the three succeeding sampling dates showed a progressive decrease in the mite population, with the live mites mostly in the adult stage, indicating a definite ovicidal effect. The final counts totalled 2 mites in the treated plot and 1,706 in the untreated plot (Table 1), or practically no survival. Spraying Wade bush beans in pots during late August gave unsatisfactory results (Table 1). Final counts indicated an 82 per cent survival on the basis of comparison with prespray counts. An 89 per cent control was attained on the basis of a comparison of surviving mites with the 2,514 in the untreated plot.

Spraying with Ovotran on potted Burpee bush beans in September, 1953, gave excellent control (Table 1). The initial kill was not rapid but a gradual decline in the mite populations occurred compared with a rapid increase in the mite populations in the untreated plot. The final counts totalled 34 mites in the 6 treated plots and 1,489 in the untreated plot, or a 98 per cent control. A survival rate of 6 per cent was obtained on the basis of comparison with prespray counts.

CHLOROBENZILATE.[6]—Potted Burpee bush beans were sprayed September 7, 1953, with 25% chlorobenzilate wettable powder. Some residual value was shown during the 9 days this experiment was in progress (Table 1) as evidenced by a 15 per cent survival based upon comparison with prespray counts and a 95 per cent control.

DIAZINON.[6]—Potted Burpee bush beans sprayed with 25% Diazinon wettable powder resulted in excellent initial kill of nymphs and adults but 9 days later there was a survival rate of 49 per cent over prespray counts and a control of only 30 per cent (Table 1), was attained. No effect on the mite eggs was noted.

EPN 300.[7]—Spraying potted Wade bush beans was unsatisfactory in the control of mites (Table 1), with poor control indicated after 9 days.

MALATHION EMULSIFIABLE LIQUID.—Potted Wade bush beans were sprayed August 13, 1953, at the rate of one tablespoonful (14.7 ml.) of 57% malathion emulsifiable concentrate per gallon of water or 3.1 pints per 100 gallons of water. A fair degree of control (Table 1) was obtained after 9 days, as evidenced by a 12 per cent survival rate, based upon comparison with prespray counts and an 88 per cent control based upon comparison with untreated plants at the end of 9 days.

Even after the experiments were closed, plants in beds sprayed with Aramite and Ovotran developed more new leaf growth than plants in the adjacent malathion-treated and untreated plots.

SUMMARY.—The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, is generally distributed throughout Kansas and usually abundant every year both under greenhouse and field conditions. Experimental acaricidal control tests were conducted during the summer of 1953 on Burpee, Green Stringless Pod, and Wade bush beans grown in beds and earthenware pots.

Single treatments with wettable powder sprays gave control after 19 days as follows: 15% Aramite, 99%; 25% malathion, 14%; and 50% Ovotran, 99.9%. Ovotran showed an ovicidal effect. Malathion produced good initial kill but the need for repeated applications was indicated.

In tests using potted plants and extending over 9 days Aramite gave 94% control, malathion 91%, and Ovotran, in mid-August, 89% and in early September, 98% control. Chlorobenzilate gave 95% control. Diazinon gave quick initial kill but only 30% control at the end of 9 days. EPN 300 gave 85% control. An 88% control was obtained with malathion, 57% emulsifiable liquid, applied at a rate of 1 tablespoonful per gallon of water.

The three varieties of bush beans used exhibited the same degree of susceptibility to mite infestations. Green Stringless Pod beans sprayed with 25% malathion wettable powder showed a few leaves with yellowing as compared with adjacent treated and untreated plots in these experiments.

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[5] Supplied by Dow Chemical Co., Midland, Michigan.
[6] Supplied by Geigy Co., New York, N. Y.
[7] Supplied by E. I. du Pont de Nemours and Co., Wilmington, Del.

Schradan Content in Field Grown Peas in Relation to Pea Aphid Control[1]

T. B. Davich and J. W. Apple,[2] *University of Wisconsin, Madison*

The systemic insecticide schradan,[3] octamethyl pyrophosphoramide, has been shown to possess excellent insecticidal properties against the pea aphid, *Macrosiphum pisi* (Harr.), on canning peas in Wisconsin by Davich & Apple (1951) and Bronson & Dudley (1951). The experiment presented in this paper was conducted during 1952 on peas growing under field conditions in an attempt to determine the level of schradan within the plant necessary for aphid control. Previously, behavior of schradan in vegetable crops had been studied with chemical (Ripper *et al.* 1950), biological (Wallace 1951, Zeid & Cutkomp 1951, Dowdy & Sleesman 1952 and Reynolds *et al.* 1953) and radioactive tracer (David 1951 and Heath *et al.* 1952) techniques. Casida *et al.* (1952), using chemical and biological procedures, have demonstrated various aspects of its behavior in the pea plant, under greenhouse conditions. However, little is known concerning its behavior following field application to peas, and residue data in shelled peas are practically wanting.

Methods.—Perfection peas were planted on May 19, 1952, on Miami silt loam soil. On June 26, when the plants were at the 13 node stage, foliage sprays were applied to provide $\frac{1}{4}$, 1, 4, and 8 pounds of schradan per acre in 50 gallons of water. The experiment contained four replications of a randomized complete block design and included unsprayed check plots.

Aphid counts were taken 2, 9, 14, and 21 days after application of the spray. Five plants from each plot, or a total of 20 per dosage, randomly selected, were cut off at ground level and examined for aphids. These same plants were used to determine the content of schradan. Two equal-weight plant samples were selected at random. One sample was used to obtain dry weight while the other was used to estimate the schradan content by chemical analysis. These analyses were based on the procedure proposed by Ripper *et al.* (1950) for the detection of schradan which involves the molybdenum-blue method for the estimation of phosphates as suggested by Allen (1940). The analytical method used in this study differed from Ripper's in that hydrolysis of the extracted schradan was accomplished by storing the extracts for 2 months in hydrochloric acid instead of refluxing with the acid. Schradan residues reported in this paper were unreplicated determinations.

Results.—Table 1 presents a summary of the surviving aphid populations and schradan residues resulting from the use of four dosages of schradan when applied as foliage sprays. Although aphid counts were made 2, 9, 14 and 21 days after treatment, only the data from the first three dates are included because excessive aphid mortality occurred just prior to the 21-day count as a result of fungus infection. True differences between aphid populations were determined by first transforming aphids per plant into $\sqrt{\text{aphids per plant plus } 0.5}$ and then subjecting these data to an analysis of variance test. Dosages proved to be significant at each date of observation so a multiple comparison test as suggested by Duncan (1951) was employed to establish differences between dosages. A summary of these statistics is given in table 2.

Discussion.—Throughout the 14-day observation period the 4-pound dosage proved to be as effective in the control of pea aphids as the very excessive 8-pound rate. The 4-pound dosage was superior to the 1-pound dosage, especially at the first observation date. The 1-pound and $\frac{1}{4}$-pound dosages and the untreated check showed no real differences in aphid control 2 days after treatment. However, they were significantly different from each other 9 days after treatment. On the 14-day count, 1 pound showed significantly better control than the $\frac{1}{4}$-pound dosage; while the latter was no different from the untreated check.

High initial pea aphid control (98%) resulted only with

Table 1.—Pea aphid populations and schradan content of pea plants at intervals after foliage application of schradan to canning peas.

Days After Treatment		Untreated Check	Pounds Schradan per Acre			
			0.25	1	4	8
2	Aphids per plant	13.1	11.2	6.7	0.3	0.0
	P.p.m. schradan[a]		19.9	30.4	109.2	266.8
9	Aphids per plant	24.0	17.4	2.3	0.2	0.0
	P.p.m. schradan		13.6	31.5	64.2	105.4
14	Aphids per plant	26.6	22.4	9.2	1.2	0.05
	P.p.m. schradan		0.0	0.6	9.0	19.8
	Foliage residues at harvest					
21	P.p.m. schradan		0.0	0.0	4.8	11.2
	Residue in fresh peas					
22	P.p.m. schradan		0.0	0.0	3.2	6.5
	Residue in pods					
22	P.p.m. schradan		0.0	0.0	0.0	0.0

[a] Dry weight basis.

Table 2.—Pea aphid control following foliage applications of schradan.

Days After Treatment		Pounds Schradan per Acre				
		8	4	1	0.25	Untreated Check
2	Control[a]	100.0	98.0	49.0	14.0	
	A/P[b]	0.0	0.3	6.7	11.2	13.1
		[c]				
9	Control	100.0	99.0	90.0	28.0	
	A/P	0.0	0.2	2.3	17.4	24.0
14	Control	99.8	95.5	65.4	15.8	
	A/P	0.05	1.2	9.2	22.4	26.6

[a] Per cent control based on untreated check.
[b] Aphids per plant.
[c] Means underscored by the same line are not significant at the 5% level.

[1] Approved for publication by the director of the Wisconsin Agricultural Experiment Station. Accepted for publication November 27, 1954.
[2] Formerly Research Assistant in Department of Entomology, at present Associate Entomologist, Virginia Agricultural Experiment Station, Holland, and Professor of Entomology, University of Wisconsin, respectively.
[3] Obtained through the courtesy of Monsanto Chemical Co., St. Louis, Missouri. Technical material composed of 70% schradan, 20% related amides and 10% inert materials.

the 4- and 8-pound dosages of schradan where the quantities of toxicant within the plants were 109 and 266 p.p.m., respectively. However, 9 days after treatment, the 1-pound dosage resulted in 90 per cent aphid reduction even though the schradan content of the plants was found to be no higher than 31.5 p.p.m.

Fourteen days after treatment the schradan content in all plots was less than 10 per cent of that measured 2 days after treatment. This loss of schradan as determined by chemical means was corroborated by the fact that aphid populations were on the increase even on plants containing as much as 19.8 p.p.m. of schradan.

Schradan residues were found in harvested peas only in the case of those plants treated with 4- and 8-pound dosages. The lack of any measurable residue in shelled peas from plants treated 21 days before harvest with 1 pound per acre along with the relatively high aphid control obtained in this test and in earlier work done by Davich & Apple (1951) and Bronson & Dudley (1951) would indicate that the 1-pound dosage approximates the quantity of schradan that might be used by a pea canner if this systemic insecticide is ever released for use on peas.

SUMMARY.—Extremely high initial control of the pea aphid was found to occur following foliage applications of schradan at rates of 4 and 8 pounds per acre. Chemical analyses 2 days after treatment indicated schradan residues of 109.2 and 266.8 p.p.m. respectively. Fourteen days after treatment, an increase in aphid numbers signified a loss of toxicity even though 19.8 p.p.m. of schradan was detected in plants treated with the 8-pound rate. Shelled peas harvested 21 days after treatment were found to contain 3.2 and 6.5 p.p.m. of schradan, respectively.

No schradan residue was detected in shelled peas from plants receiving 1 pound of toxicant per acre although this dosage did produce 90 per cent aphid control 9 days after treatment when 31.5 p.p.m. of schradan was found to be present. A $\frac{1}{4}$-pound dosage resulted in 19.9 p.p.m. of schradan 2 days after treatment but this level of toxicant was inadequate for satisfactory aphid control.

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Prevention and Control of Fly Breeding in Animal Carcasses[1]

W. C. BAKER and H. F. SCHOOF

The presence of exposed animal carcasses in communities during periods of disaster creates a serious fly breeding problem. The prodigious numbers of flies produced from this source augment the potential of disease transmission in the municipality and at the same time cause considerable annoyance to the inhabitants. Similar problems exist under wartime conditions where cadavers are subject to mutilation through fly infestation.

McDuffie *et al.* (1946) reported that preinfestation applications of orthodichlorobenzene, DDT, or BHC to dog carcasses prevented blow fly attack for several days and diminished the extent of the subsequent infestation. Treatment of infested carcasses with fuel oil solutions of orthodichlorobenzene (20 per cent), acetylene tetrachloride (10 to 20 per cent), BHC (5 per cent), or Thanite (20 per cent), or with a BHC-benzene emulsion (1 to 5 per cent), was found to be effective in destroying an established infestation.

In the present studies, emphasis was placed upon evaluating the effectiveness of five chlorinated hydrocarbon and two organic phosphorus compounds in preventing or controlling blow fly infestations in animal carcasses.

METHODS.—Dog carcasses averaging 25 to 50 pounds in weight were employed in these investigations. Each carcass was placed on the ground and exposed to natural infestation by blow flies. In the studies on preventing

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Ga.
Trade names are used as a means of identifying the product and their use does not constitute endorsement by the U. S. Public Health Service.
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infestation, the carcass was sprayed immediately after exposure. In the postinfestation tests, the carcasses were exposed for 3 to 4 days to blow fly attack before treatment was applied. As a protection against multilation by scavengers each carcass usually was enclosed in an open-topped wire cage 4-ft. square. Excluding the animals used in preliminary tests and for check purposes, a total of 80 carcasses was employed in the experiments.

All treatments were made with a 3-gallon compressed air sprayer equipped with a #5002 nozzle tip.[2] Each carcass was sprayed in position on the ground, 500 milliliters of insecticide being used for each animal. Special emphasis was placed on treating the ground-body line and the body openings. The former included a 2- to 3-inch strip of soil around the perimeter of the body. In the postinfestation studies, treatment was extended to include all visible larvae.

The test formulations were prepared from concentrates of 10 to 50 per cent toxicant in xylene plus 2 per cent Triton X-100 as the emulsifying agent. While initial tests indicated little difference in effectiveness between xylene emulsions or fuel oil solutions[3] of the toxicants involved, the reduced cost and transportable bulk of the emulstions made them the formulations of choice.

Appraisal of the preventive tests was obtained from a visual comparison of the magnitude of the blow fly infestation in each treated carcass with that found in the untreated animal. In the postinfestation studies, the effectiveness of the chemical was based upon the estimated percentage of larval mortality after treatment and upon the time interval ensuing before the carcass became reinfested.

RESULTS.—Shortly after exposure, the animal carcasses were subject to attack by several species of flies. The predominant species was the secondary screw-worm, *Callitroga macellaria;* other minor species being *Ophyra* spp., *Sarcophaga* spp., and *Musca domestica.* Egg masses usually were evident within 1 hour after the carcass was exposed, the flies depositing their eggs chiefly along the body-ground line and also in the body openings and the skin folds at the leg joints. Where a bloated carcass ruptured and exposed the body cavity, this also served as a site for oviposition. If such a rupture exposed fatty tissue only, little if any egg deposition was observed.

Untreated carcasses when heavily attacked were reduced to bones, hair, and skin within 10 to 14 days. Carcasses protected by chemical treatment gradually became shrunken but otherwise remained in good condition for 2 to 3 months. However, treated carcasses which ruptured during shrinkage, particularly behind the last rib, usually became infested through the opening. The extent of such infestations apparently was governed by the age of the carcass at the time of rupture.

In the preinfestation treatment series (Table 1) endrin, and Diazinon at 0.25 per cent strength or above provided the carcasses with 30 days or more protection from infestation. Dieldrin in a single test at 0.25 per cent also gave 30 days protection but results at 0.5 per cent were erratic, three of the five carcasses being free from infestation after 30 days while the other two were protected for only 16 and 22 days.[4] Aldrin in one test at 0.25 per cent gave 26 days protection while malathion at 0.25 per cent, BHC at 1 to 2 per cent, and chlordane at 0.5 per cent prevented infestation for periods of 7 to 20 days.

Table 1.—Effectiveness of several insecticides in protecting animal carcasses from blow fly infestations.

INSECTICIDE	PER CENT[a]	NO. OF CARCASSES	AVERAGE NO. OF DAYS PROTECTION	PER CENT REDUCTION OF EXPECTED INFESTATION
Endrin	0.5	2	30+	100
	0.25	1	30+	100
Diazinon	0.5	1	30+	100
	0.25	1	30+	100
Dieldrin	2.0	2	30+	100
	1.0	2	30+	100
	0.5	5	26	99+
	0.25	1	30	99+
Aldrin	0.25	1	26	98
Malathion	0.5	2	22[b]	99+
	0.25	2	16	99
Chlordane	1.0	2	21[b]	99+
	0.5	1	7	65
BHC[c]	2.0	1	14	40
	1.0	2	20	70

[a] Concentration of insecticide W/V.
[b] Indicates that one or more of the carcasses were protected for more than 30 days.
[c] Fifteen per cent gamma isomer.

When the magnitude of the infestation present in the treated animals attacked was compared to that obtained in the untreated carcasses, a 98 to 100 per cent reduction in anticipated infestation was apparent with all formulations except chlordane at 0.5 per cent and BHC (Table 1).

The presence of an effective treatment on the dog carcass failed to deter the blow flies from attempting to attack the carcass. Numerous eggs were laid on the carcass despite the heavy mortality ensuing among the adults contacting the animals. Dead adults frequently accumulated to a $\frac{1}{2}$" depth around a carcass. Even when female flies obviously were affected by the toxicant, they would continue to oviposit.

When carcasses were attacked by carnivores or by vultures the principal sites of attack were the eye, tongue, and anal area. Occasionally an opening was made in the lateral portion of the carcass. Untreated areas thus created were exposed to attack by flies but the invading larvae usually were unable to complete development except in ruptures at the anal area.

In certain instances a few of the many thousands of newly hatched larvae were successful in crossing the insecticidal strip at the ground-body line and completing their development beneath the carcass. Carcasses in which the infestation was of this limited nature were

[2] Spraying Systems Company, Bellwood, Illinois.
[3] Fuel oil solutions alone were not effective in preventing or controlling blow fly infestations in carcasses.
[4] In instances where erratic results occurred, the variations arose from differences in carcass size and from the occurrence of ruptures during the bloating and shrinking of the individual carcasses, which rendered certain specimens more susceptible to infestation.

Table 2.—Destruction of blow fly infestations in animal carcasses by treatment with insecticides.

Insecticide	Per Cent[a]	No. of Carcasses	Per Cent Kill		Days Protected from Reinfestation
			Range	Ave.	
Diazinon	0.5	3	100	100	30[b]
	0.25	3	100	100	30
Endrin	0.5	4	100	100	30+
	0.25	2	100	100	26[b]
Dieldrin	2.0	2	100	100	30+
	1.0	2	100	100	30+
	0.5	4	95–100	99	27[b]
	0.25	3	95–99	98	30[b]
Malathion	1.0	1	100	100	13[b]
	0.5	3	100	100	30[b]
	0.25	3	100	100	27[b]
Aldrin	0.5	3	99+–100	100	21[b]
	0.25	3	55–100	85	17[b]
Chlordane	2.0	3	35–100	77	27[b]
	1.0	2	95–98	97	30[b]
BHC[c]	5.0	2	98–99+	99	18
	4.0	1	75	75	30+
	1.0	1	30	30	30
	0.5	2	40	40	—

[a] Concentration of insecticide W/V.
[b] Indicates one or more of the carcasses were protected for more than 30 days.
[c] Fifteen per cent gamma isomer.

rated at the 99 plus per cent level of reduction (Table 1).

The data from tests where infested carcasses were treated are given in table 2. Complete kill of all mature larvae was obtained with malathion (0.25 per cent), Diazinon (0.25 per cent), endrin (0.25 per cent), dieldrin (1.0 per cent), and aldrin (0.5 per cent). At strengths of 0.25 and 0.5 per cent, dieldrin produced mortalities of 95 to 100 per cent. Chlordane at 1.0 and 2.0 per cent yielded 95 to 100 per cent kills with four carcasses but in the fifth carcass only 35 per cent of the infestation was destroyed. A similar failure was noted with aldrin at 0.25 per cent.

After the destruction of the established infestations, carcasses treated with dieldrin, endrin, chlordane, and Diazinon remained free of further infestation for 26 to 30 plus days. Except for the single test at a 1.0 per cent strength, malathion provided protection of a similar duration. BHC and aldrin gave erratic results at the strengths tested.

Although dieldrin and endrin treatments provided mortalities equivalent to those produced by the Diazinon and malathion, the speed of action of the latter compounds in immobilizing the larvae was much greater. Thirty minutes after treatment with Diazinon or malathion, 50 to 80 per cent of the larvae were inactive, with about 99 per cent succumbing in 5 hours. In contrast, larval movement persisted for periods of 24 to 48 hours after the maggots were sprayed with dieldrin or endrin.

Discussion.—Based on the consistency of the results obtained at minimal strengths, Diazinon, endrin, and dieldrin appear to offer the most promise of the insecticides tested. Aldrin and malathion yielded poor results on certain carcasses but further data are required before they can be considered inferior to the previously named compounds.

Chlordane at a 1 per cent strength gave results approaching those achieved at 0.5 and 0.25 per cent with Diazinon, endrin, dieldrin, malathion and aldrin. BHC did not appear as effective as the other chemicals but on the basis of the gamma isomer content the dosages employed were much lower than those of the other compounds.

Summary.—Dog carcasses were treated with emulsion applications of dieldrin, endrin, aldrin, malathion, Diazinon, BHC and chlordane to evaluate the efficacy of each toxicant in preventing blow fly infestation of the carcass or in controlling established infestations. Dieldrin at 0.25 to 2.0 per cent strength, endrin at 0.25 to 0.5 per cent, and Diazinon at 0.25 to 0.5 per cent prevented blow fly infestations for 26 to more than 30 days and gave a 98 to 100 per cent reduction of established infestations. Malathion at 0.25 to 0.5 per cent produced 100 per cent kill of the mature larvae on infested carcasses but was less effective than dieldrin, Diazinon, or endrin in preventing blow fly invasion of carcasses. Aldrin was similar to malathion in its overall effectiveness. Chlordane at 1.0 per cent yielded results paralleling those achieved with dieldrin, endrin, aldrin, Diazinon, and malathion at 0.25 to 0.5 per cent levels. BHC was the least effective of the compounds tested.

The organic phosphorus compounds produced an effective kill of mature blow fly larvae much more rapidly than the chlorinated hydrocarbon insecticides.

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Control of the Clover Root Curculio on Alfalfa with Notes on Life History and Habits[1]

G. W. Underhill,[2] E. C. Turner, Jr., and R. G. Henderson, *Virginia Agricultural Experiment Station, Blacksburg*

Complaints of alfalfa stands dying out in Virginia have increased over the past several years. An examination of plants from some alfalfa fields in which the stand was dying out, revealed the presence of a number of insect injuries and common diseases. Of particular notice were injuries to roots caused by the clover root curculio, *Sitona hispidula* (F.). Surveys revealed that this insect is one of the most common and injurious pests of alfalfa in Virginia. Most of the damage by this insect is done by the larvae which feed on the tap and secondary roots leaving moderate to severe wounds. Plants thus injured become less vigorous resulting in loss both in yield and stand.

A suggestion of root rot was often present on these damaged roots. In order to study a possible relationship between diseases and root feeding insects, certain soil treatments with residual insecticides were made with the hope of getting protection against one or the other or both of these troubles. An attempt was also made to correlate the timing of these insecticide treatments with certain life history habits of the insect. This paper is a progress report on these exploratory tests.

Life History and Habits.—Notes by Bigger (1930) in Central Illinois indicate that the clover root curculio adults emerge from May to July, with the peak of emergence in June. They become sexually mature in the fall. Egg laying occurs in October and November and during warm spells in the winter; however, approximately 75 per cent of the eggs are laid in the spring. There is one generation a year.

Some unpublished notes were recorded by the senior author at Chester, Va., in 1920 on 15 pairs of the clover root curculio. They were kept in insectary cages from early April until all adults had died. Oviposition data showed that approximately 60 per cent of the eggs were laid in April, 35 per cent in May and 5 per cent in June. The peak of oviposition occurred from April 15 to 25. The maximum number of eggs laid per female was 498, with an average of 218 for all females during this period. The eggs hatched in about 3 weeks. Observations on the hatching of 665 eggs showed an incubation average of 26 days for eggs laid in April and 23 days for eggs laid in May. Bigger (1930) stated that eggs hatched in about 3 weeks during the spring, but in the winter, required 150 to 200 days.

The adults are found chiefly on the soil surface under the host plants throughout the year. Alfalfa leaves are notched by the feeding of adults but very little visible damage is observed. After emergence of the adults in the latter part of June and first part of July, they disperse in all directions within and outside of the field. In collections made by insect net near Blacksburg, Virginia, during the summer of 1952 as many adults were caught in pastures and fields around the alfalfa field as were caught in the alfalfa field itself.

In the fall, the adults begin moving into alfalfa fields after being fairly inactive for most of the summer. These insects are relatively poor flyers and most of their travel is confined to crawling; however, some are capable of flying long distances. Tanglefoot screens placed 2 to 6 feet from the ground in and around alfalfa fields showed only a few adults flying into the fields. Trench traps placed similarly in the same fields caught large numbers of adults. This indicated that most of the dispersal of the adults is by crawling.

Injury.—Practically all of the injury by this insect is done in the larval stage. The damage to the roots of young alfalfa is surprisingly severe. Most of the root injury occurs from early March through June. This can be called the "critical injury period." In addition to feeding on the side roots and rootlets of alfalfa, irregular feeding channels are made on the tap roots of the plants, sometimes completely girdling the root. Injury to the roots was found to a depth of 10 inches or more although most of the damage seemed to occur within the upper 4-inch zone.

Some observations on root injury the first and second seasons after the alfalfa was planted are summarized in table 1. Plants heaved out of the ground by winter freezing and thawing were gathered and plants not heaved out were dug. They were examined for root injury and it was found that 86 per cent of the winter heaved plants and 80 per cent of those not winter heaved were injured to some extent by the clover root curculio the first season. The second season damage occurred on practically all of the plants whether winter heaved or not. The degree of injury, however, showed considerable difference as shown by the percentage of the plants moderately to heavily injured. The first and especially the second season there was a much greater amount of root injury on the winter

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[2] Retired from active duty September 1953.

Table 1.—Injury to alfalfa roots by the clover root curculio on plants winter heaved and plants not winter heaved. Blacksburg, Va. 1951–52.

	Plants Examined	Degree of Injury (Per Cent)		
		None	Light	Mod. Heavy
	First Season			
Winter heaved	2,531	14.0	54.0	32.0
Not winter heaved	720	20.0	69.0	11.0
General average		15.1	57.9	27.0
	Second Season			
Winter heaved	472	0.2	28.7	71.1
Not winter heaved	253	2.8	76.5	20.7
General average		0.6	35.8	63.3

heaved plants than on the plants not winter heaved. Thus, it appears that this injury causes an increase in the amount of winter heaving in alfalfa stands by weakening the plant and its root system.

CONTROL TESTS.—Preliminary tests were made in 1950 to 1951 to determine the effectiveness of several insecticides, applied in the soil, on the control of the clover root curculio. The treatments were made at Blacksburg and Richmond, Virginia. The test plots near Richmond were located in a field where alfalfa had grown for many years and the soil was known to be infested with the stem nematode, *Ditylenchus dipsaci* (Kuhn) Filipjev, in addition to the common pests of alfalfa. The plots at Blacksburg were located in a field that had been seeded to alfalfa the fall prior to the beginning of the test but the stand was lost the following spring due to what appeared to be severe clover root curculio injury. The plot size in both tests was 7 by 20 feet. The insecticides to be tested were weighed for each plot and mixed with the fertilizer being applied. The mixture was then spread over the plot and worked into the soil to a depth of 3 to 4 inches. These plots were randomized and replicated four times at Blacksburg and two times at Richmond.

More extensive tests were made in 1952 and 1953 on a farm near Blacksburg, and, although the field used had not grown alfalfa immediately before the tests, clover host plants of the clover root curculio were growing in adjacent areas. In an attempt to correlate the time of application of the insecticides with certain activities in the life history of the insect, applications were made in August, October and early March. Plots 20 feet wide by 30 feet long were employed. The first application of the insecticides was made prior to seeding of alfalfa in August 1952 and was applied in the same manner as in the preliminary tests. All later treatments were made after seeding by hand-applying the insecticide, in the wettable powder form mixed with moist sand, to the soil surface. No attempt was made to incorporate the material in these later treatments into the soil.

In another series of treatments an attempt was made to find the most effective time of application in the spring. It was set up using a field near the earlier experiments. The alfalfa in this test was 2 years old and 68 per cent of the plants had already been found infested the first season. In some cases in the two tests, repeat applications were made at a later date using the same dosage rate as applied in the original application. A split plot design was employed in these tests.

A number of plants were dug and the roots were examined for insect injury during the summer following the insecticide applications. In the preliminary tests 20 plants were dug per plot and in the later tests from 30 to 50 plants per plot were examined. Each plant in these samples was examined for the degree of root injury and placed in one of five categories: none, slight, moderate, heavy, and severe. Scoring values of 0, 1, 3, 5, and 7, respectively, were assigned. The weighted average, using these values, was then calculated. The per cent of plants damaged was computed simply by calculating the per cent of plants not injured and substracting from 100.

PRELIMINARY TEST RESULTS.—All the insecticides at the rates used gave a reduction of root injury, as shown in table 2. The degree of control varied somewhat but, in general, the results were consistent in the two tests although the degree of injury in the untreated checks was much higher in the Richmond tests. Aldrin and chlordane, at the rates used, gave the most effective control.

Table 2.—Results of soil applications of insecticides for the control of the clover root curculio.[a]

INSECTICIDE	POUNDS ACTIVE INGREDIENT (PER/ACRE)	DEGREE OF ROOT INJURY[b]	
		Blacksburg	Richmond
Aldrin	4	0.8	1.0
Dieldrin	2	1.0	3.0
Chlordane	10	0.5	0.5
Lindane	1	1.8	6.0
Check		3.2	7.0

[a] Treatments made August, 1950; readings taken June, 1951.
[b] Weighted average, based on a grading system of 0, 1, 3, 5, and 7; the 0 being free from injury and 7 was rated as the heaviest injury.

The plants from these tests were examined for root diseases. Fusarium wilt occurred on a number of plants taken from the plots at Richmond. The percentage of infected plants was low, however, and was not correlated with insect injury. It was not possible to made observations on Fusarium wilt on these plots in succeeding years. Root diseases were not detected in the plots located at Blacksburg.

RESULTS, 1952–53.—Treatments made in August prior to the seeding of alfalfa and especially treatments made on October 15 showed good control of the clover root curculio injury. These data are shown in table 3. Aldrin, dieldrin and chlordane especially at the higher rates of application showed good control. Toxaphene in general appeared to give poorer control than the other materials. On the other hand, application of these materials on March 6, showed a decrease in the effectiveness of the treatments. Heptachlor, which unfortunately was not included in the earlier tests, showed good control at 4 pounds per acre.

Repeat treatments of certain plots made on March 20, 1953 showed a moderate reduction in the amount of root injury in the August series of applications. This reduction in root injury was not consistent in the October and March series and may not show any increased control.

RESULTS OF OTHER SPRING TREATMENTS.—Applications of aldrin, chlordane, and heptachlor were made in three different series of tests on March 11, March 24 and June 1, 1953. Because these treatments were not applied until the second season after seeding more root injury was expected in all tests than when treatments were made during the first season. Comparison of the treatments in table 4 show that, in general, spring treatment was not as good as expected. Heptachlor seemed to show the most effective control although later treatments in the spring with this material showed increasingly less control. Applications of insecticides on June 1 resulted in almost no control whatever. Treatments applied earlier and repeated June 1 showed only slight increase in control.

Table 3.—Applications of insecticides on first-year alfalfa for control of clover root curculio. Blacksburg, Va. 1952–53.

Insecticide	Pounds of Active Ingredient (per Acre)	Root Injury: Per Cent Plants Infested	Root Injury: Degree of Injury[a]
August 1952 (In soil just prior to seeding)			
Aldrin	1	58	1.2
	2	58	1.4
	2[b]	40	0.8
	4[b]	29	0.7
Dieldrin	1	72	2.5
	2	38	1.1
	2[b]	42	0.9
	4[b]	20	0.4
Toxaphene	5	70	3.4
	10[b]	52	1.6
Check	—	82	3.1
October 15, 1952 (Soil surface treatments)			
Aldrin	2	57	0.8
	2[b]	32	0.6
	4	60	0.9
	4[b]	33	0.5
Dieldrin	2	30	0.3
	2[b]	25	0.4
	4	44	0.9
	4[b]	40	0.5
Chlordane	5	62	0.9
	5[b]	47	0.9
	10	45	0.7
	10[b]	36	0.4
Toxaphene	6	62	1.1
	6[b]	67	1.2
Check	—	83	3.0
March 6, 1953 (Soil surface treatments)			
Aldrin	2	68	2.7
	2[b]	74	1.9
	4	64	2.7
Dieldrin	2	80	3.3
	1[b]	76	2.9
Chlordane	5	56	1.6
	10	58	1.5
Heptachlor	4	32	0.7
	8	25	0.4
Check	—	94	4.6

[a] Weighted average, computed as for Table 2.
[b] Treatments repeated, using a split plot design—March 20, 1953.

Discussion.—Studies made on the life history and migrating habits of the clover root curculio have revealed some rather interesting explanations of the results of the experiments. As stated previously, the adults become sexually mature and quite active in the fall. Studies indicate that many adults begin moving into the alfalfa fields in the middle of September. Soil insecticides applied in the fall, just before or during that peak of activity seem to kill most of the adults before many eggs are laid. Thus, an application of the insecticides just prior to seeding of alfalfa gave fair control, and an application in October gave what appeared to be better control. This difference in control indicates that timing of the applications will increase the effectiveness of the insecticides. Spring applications gave poor control with the exception of heptachlor. This poor control by spring treatments indicates that many eggs had already been laid and that the larvae had gone into the ground where they partially escaped the effects of soil surface applications.

It is unfortunate that all tests were not applied on 1-year-old alfalfa because the results could have been more comparable and easier to differentiate. The tests made at various times in the spring of 1953 on 2-year-old alfalfa resulted in poor control; however, there was some indication that control was better on the early spring treatments. If this is true, here again there is possibly a correlation with the life history of the insect. As shown previously, the egg laying of the adults increases later in the spring. Therefore, the later the insecticide is applied, the greater the chances that the larvae can escape the effect of the insecticide.

Repeat treatments in the August series of applications showed a moderate increase in control, but the repeat treatments in the October series showed no increase in control. The repeat treatments in the March series of applications showed only slight increase in control.

Of the insecticides tried, dieldrin, aldrin, chlordane and heptachlor seem to show some promise, although the dosage levels of these insecticides were fairly high. Apparently, once the most effective date of application is found, the dosage levels can be reduced, thereby making such treatment economically feasible.

Table 4.—Spring applications of insecticides to the soil surface for control of the clover root curculio on 2-year-old alfalfa. Blacksburg, Va. 1953.

Insecticide	Pounds of Active Ingredient (per Acre)	Root Injury: Per Cent Plants Infested	Root Injury: Degree of Injury[a]
March 11, 1953			
Aldrin	2	76	2.7
	2[b]	85	3.7
	4	90	2.7
Chlordane	2.5	70	2.2
	2.5[b]	87	2.8
	5	90	2.9
Heptachlor	2	66	1.9
	2[b]	82	1.7
	4	53	1.3
Check	—	88	3.5
March 24, 1953			
Aldrin	4	70	1.6
	2[b]	89	2.7
Chlordane	2.5	93	2.9
	5	91	3.4
	5[b]	88	2.4
	10	79	2.5
Heptachlor	2	77	2.2
	4	95	3.1
	4[b]	78	1.9
	8	63	1.3
Check	—	95	3.8
June 1, 1953			
Aldrin	2	86	3.3
	4	94	3.1
Dieldrin	1	83	2.7
	2	91	3.7
Chlordane	2.5	75	1.9
	5	73	2.1
Heptachlor	2	88	3.8
	4	83	2.3
Check	—	95	3.8

[a] Weighted average, computed as for Table 2.
[b] Treatments repeated, using a split plot design—June 1, 1953.

SUMMARY.—Surveys of alfalfa stands in Virginia revealed the presence of a number of common diseases and insects. Of particular notice were injuries caused by the clover root curculio *Sitona hispidula* (F.). The life history of this insect is briefly reviewed. Studies on the root damage by the larvae indicate that injury to first year alfalfa is surprisingly severe. It was also found that damage to the roots was much greater in plants heaved out of the ground by winter freezing and thawing. Although it was suspected that the wounds inflicted by the insect would provide entry by many root-rot organisms, such a correlation was not found in preliminary examination.

Preliminary tests using soil insecticides were successful enough to warrant further investigation. Several insecticides at various dosage levels were applied to the soil prior to seeding and incorporated in the soil. Later applications were made to the soil surface at various times during the season. Aldrin, dieldrin, and chlordane gave good results when applied prior to seeding or later during the fall. A correlation was found between the time of application and the life history of the insect. Fall activity and migration of the adult appeared to coincide with the excellent control obtained by the fall application. Spring application showed poor control with these same materials. Heptachlor, which was included in the spring treatments, showed good control. Unfortunately this material was not used in the fall treatments. Several spring treatments were made on 2-year-old alfalfa but with poor results. There was some indication that early spring treatments are more effective than later spring treatments.

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Internal Medication of Plants for the Control of Insects

ROGER F. ANDERSON,[1] *School of Forestry, Duke University, Durham, N.C.*

The introduction of substances into the sap of plants for the purpose of controlling insects or diseases has long attracted interest. Direct vascular injections have been most commonly used, but in recent years root and leaf absorption of the materials have been receiving greater consideration. The use of root absorbed poisons was stimulated by the work of Nelson *et al.* (1933) who found that selenium absorbed by the roots of plants and translocated to the aerial parts was highly toxic to animals eating the plants. Subsequently, Hurd-Karrer & Poos (1936) demonstrated that selenium absorbed by plants was effective against the apple grain aphid, *Rhopalosiphum prunifoliae* (Fitch), and the spider mite, *Tetranychus telarius* (L.), when these fed on cereal plants grown in soil or in nutrient solutions containing sodium selenate at concentrations apparently harmless to the plants. Others, including Morris *et al.* (1941) and Kiplinger & Fuller (1946), have continued the work with the use of sodium selenate for the control of spider mites; however, the great toxicity of selenium to mammals makes its use as an insecticide or acaricide very undesirable.

R. R. Whitten (1942) treated the soil of two red pines (*Pinus resinosa* Ait.), growing in butter tubs, with quassia extract and noted that these trees remained free of the sawfly, *Neodiprion sertifer* (Geoffroy); whereas eight untreated pines were completely defoliated.

The chemical disodium ethylene bis-dithiocarbamate was reported by Turner (1945) to have been absorbed by the roots of several crop plants and to have had an adverse effect on the insects infesting the plants.

Several people have found that a few of the newer synthetic insecticides are absorbed and translocated in sufficient quantities to be toxic to feeding insects. These include Questel & Connin (1947), Granger & Leiby (1949) and Starnes (1950) for parathion and Starnes (1950) for BHC, but up to the present time the most important of the insecticides for use in internal medication however, are probably schradan and Systox. Recently a good bibliography has been compiled on these and other systemic insecticides (Giang 1954).

In the present work, which was conducted during 1947 and early 1948, schradan and Systox were unknown to the writer but a number of chemicals were tested. Of these, quassia and parathion appeared most promising as root absorbed internal plant insecticides. The studies made with these two materials are discussed in the present paper.

TESTS WITH QUASSIA (PICRASMIN).—The quassia extract used was a dark brown, extremely bitter, viscous liquid. The container label indicated that the material was "solid extract quassia, Picrasma excelsa Lindl., 1 part represents 10 parts drug." Quassia from this species of woody plant is known as Jamaican quassia. The active constituent of Jamaican quassia is picrasmin, as isomer of quassin and neoquassin Clark (1938). The latter two are obtained from another tropical woody plant. A sample of pure picrasmin was supplied by R. C. Roark of the Insecticide Division, of the former Bureau of Entomology and Plant Quarantine.

The method of application was simple. The extract or chemical was mixed with water and poured on the soil surface of the pots containing the growing plants. At various periods of time following treatment the aerial parts of these plants were fed to the test insects.

In table 1 data are presented of tests with the Mexican bean beetle larvae, *Epilachna varivestis* Muls. The bean

[1] The work reported in this paper was done while the writer was employed by the former Bureau of Entomology and Plant Quarantine, U.S.D.A. at Beltsville, Md. The writer is grateful to Dr. F. C. Craighead for his interest and aid in conducting the work. Accepted for publication December 1, 1954.

Table 1.—Mortalities of Mexican bean beetle larvae fed leaves from plants growing in soil treated with quassia.[a]

Larval Instar	Grams Quassia Extract per Pot	Per Cent Mortality During 1 Week	Total Larvae Tested
First	0.12	42	20
	.25	52	39
	.50	69	40
	1.00	83	39
	2.00	100	40
Second	0.25	20	15
	.50	27	15
	1.00	13	35
	2.00	45	35
	4.00	84	20
	8.00	94	20
Third	4.00	15	15
	8.00	31	15
	12.00	46	15
	16.00	15	15

[a] Fifteen to 20 larvae were used per test.

plants were grown in 6-inch flower-pots in a light sandy soil inside a glasshouse. Five plants were grown in each pot. Leaves were removed from the plants, starting 0 to 5 days following treatment, and fed to the larvae confined in petri dishes. Corrections were made for the larval mortalities which occurred on untreated plants.

Results similar to those in table 1 were obtained in a number of other tests in which the larvae fed directly on the caged plants. Mortalities of the bean beetle larvae during a 1-week period were as follows: first instar—73 to 100 per cent for dosages of 0.25 to 3 grams of quassia extract; second instar—75 to 100 per cent for 0.5 to 10 grams of extract; and third instar—5 to 25 per cent for 1 to 20 grams of extract. A total of 602 larvae were tested.

In one test which was conducted several months later than those just listed and in which 190 larvae were tested, the mortalities were much lower. Starting with first instar larvae the mortalities were only 8 to 70 per cent during a 1-week period when dosages of 0.5 to 8 grams of quassia extract were used. The reduced effectiveness may have been due to the use of a more resistant insect. On the other hand it may have been associated with the character of the soil. For example, it may have had different absorptive characteristics than that used in earlier tests.

When purified picrasmin in amounts of 1 to 20 milligrams was applied to the soil of 6-inch pots containing growing beans, the first instar bean beetle larvae feeding on these plants suffered 93 to 100 per cent mortality during the following week. Four tests were made in which 160 larvae were used. During the second week 15 to 47 per cent mortalities resulted to the 45 larvae feeding on the plants treated with 1 to 5 milligram dosages, and 100 per cent larval mortality occurred on the plants treated with 10 to 20 milligrams picrasmin. After 2 weeks the older leaves on the treated plants were almost as effective against the larvae as when first treated; whereas the leaves grown after treatment had little effectiveness. This result suggests rapid decomposition in the soil and little translocation of the chemical from the older to the younger leaves. Additional tests are needed to learn whether these suggested explanations are correct.

Table 2.—Effect of quassia extract treatments on mortality and developmental rates of Mexican bean beetle larvae.[a]

Grams of Quassia Extract per Pot	Days to Obtain 50 Per Cent Mortality	Average Developmental Stage Reached in 1 Week (Instar)
0	—	3.5
0.12	—	3.2
.25	6.6	3.0
.50	3.8	2.7
1.00	3.6	2.6
2.00	3.0	All dead
Starved	2.6	All dead

[a] Fifteen larvae were used per test.

The bitterness of the picrasmin, either when applied pure or in the extract, made it easy to detect the presence of the chemical in the various parts of the plants. Within 24 hours following treatment the leaves and fruit of bean plants became bitter.

The fact that food consumption varied inversely with dosage together with the data presented in table 2 suggests that repellency and starvation may be the mode of insecticidal action; however, in one test with a 5 per cent quassia extract spray used directly on the insects the 48 hour mortality to 60 first instar larvae was 98 per cent. Examination of larvae that died on the leaves, especially those that were confined in petri dishes, showed that they became glued by a whitish rectal excretion to the leaf surfaces before dying.

The results of tests with other species of insects infesting both herbaceous and woody plant species, against which the absorbed quassia was tried, are presented in table 3.

In the tests against aphids (table 3) the insects lived

Table 3.—Tests with absorbed quassia against various species of insects infesting herbaceous and woody plants.[a]

Insect or Mite Species	Host Plant	Grams of Quassia Extract	Diameter of Flower-Pot (inches)	Mortality[b] During 1 Week (per cent)
Spider mites				
Tetranychus bimaculatus Harvey	Bush bean	1–20	6	0
Aphids				
Macrosiphum solanifolii (Ash.)	Potato	1–10	6	0
Aphis medicaginis Koch	Lima bean	1–5	6	90
Brevicoryne brassicae (L.)	Cabbage	0.5–4	4	100
Myzus persicae (Sulz.)	Cabbage	1	4	0
		5	4	90
		10	4	95–100
Unilachnus parvus (Wilson)	Pitch pine	25	12	90
		50	12	100
Lepidopterous larvae				
Ichthyura inclusa Hbn.	Large toothed aspen	1	6	55
		2–10	6	95–100
Malacosoma americanum (F.)	Choke cherry	1–8	6	10–50
		16 & 32	6	100
Pieris rapae (L.)	Cabbage	4	4	0
Sawfy larvae				
Neodiprion lecontei (F.)	Pitch pine	25 & 50	12	100

[a] Heavily infested plants were used; therefore, the actual number of insects tested was not determined.
[b] Estimated.

longest on the younger leaves and in most instances a few remained alive on the youngest unfolding leaves. This suggests that these young leaves absorbed the chemical more slowly than the older leaves.

The larvae of *Neodiprion lecontei*, *Malacosoma americanum* and *Ichthyura inclusa* were in the first instar when the tests were started; whereas the aphids, mites, and *Pieris rapae* were of all ages when used.

The sawfly larvae were not adversely affected until about a week after the trees had been treated which suggests that this period of time was required for the picrasmin to be absorbed and translocated to the needles of the pines. In tests made 3 to 12 weeks following treatment the larvae died very rapidly, usually within 48 hours. Lack of insects prevented making additional tests at periods of time longer than 12 weeks. The treatments were 100 per cent effective against the 165 larvae tested.

TESTS WITH PARATHION.—Variable results were obtained when first-instar bean beetle larvae were fed on plants growing in soil treated with parathion. Ten to 50 mg. per 6-inch flower pot was 100 per cent effective in some tests but not in others. Treatments with as much as 50 mg. per 6-inch pot were ineffective against the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. The results of several tests against the eastern tent caterpillar, *Malacosoma americanum* (Fitch) are presented in table 4. These tests were made 7 to 42 days following treatment.

It is possible that the parathion acted as a fumigant and contaminated the foliage via the air; therefore, several observations were made regarding this possibility. After the plants had been treated they were placed about a foot apart on the greenhouse benches with the untreated check plants always interspersed among those treated; consequently, the untreated plants should have been fumigated almost as much as those treated. Mortalities of the insects fed the leaves from the untreated plants, however, were always very low compared to those which occurred to the insects fed on leaves from the treated plants.

Two tests were made to specifically test the fumigating action. For one of these 1.6 grams of parathion was mixed with soil and water and then placed in an open petri dish beneath an untreated cherry seedling containing a colony of first- and second-instar eastern tent caterpillar larvae. The tent was 4 inches above the insecticide-containing dish. During the following 10 days the insect mortality was 3 per cent. Further observations could not be made because the foliage had all been consumed. In the second test the crown of a potted cherry seedling was bent over the soil of an adjacent treated potted tree. On the crowns of each of these trees a colony of eastern tent caterpillars was established. After 5 days the insect mortality was 100 per cent for the treated plant and zero for the untreated plant. These results suggest that any fumigating action which may have occurred was of little importance in these tests.

TESTS WITH OTHER CHEMICALS.—Eight other chemicals were tested but none was found to be effective against first-instar Mexican bean beetle larvae at the dosages used. The tests were run for a period of 1 week. These chemicals and the dosages used per 6-inch pot were as follows: BHC, 11.5 per cent gamma isomer, 1 gm.; Aloin, 800 mg.; cyclohexanone oxime, 20 mg.; 2,4-dimethyl-3-pentanone semicarbonzone, 20 mg.; 4-phenylmorpholine, 20 mg.; alpha-ethyl-alpha-toluamide, 20 mg.; 1 phenyl-2-propionylhydrozine, 20 mg.; and 1-isobutyryl-2-phenylhydrozine, 20 mg. The alpha-ethyl-alpha-toluamide was phytotoxic at the concentration used. The latter six chemicals were supplied by R. C. Roark of the Insecticide Division of the former Bureau of Entomology and Plant Quarantine.

Table 4.—Mortality of eastern tent caterpillars when fed on leaves from wild cherry seedlings growing in soil treated with parathion.

Milligrams per 6-Inch Pot	Per Cent Mortality During 1 Week	Number of Insects Tested
	First Instar	
0	2	266
50	47	162
100	64	256
200	46	218
400	79	282
800	85	259
	Third Instar	
0	0	2
50	100	33
100	100	10
200	100	30
400	97	30
800	100	30
	Fourth and Fifth Instar	
0	0	10
50	60	10
100	67	9
200	100	14
400	93	18
800	94	25

SUMMARY.—Results of preliminary experiments on internal plant medication with various chemicals, for the control of insects are presented. Quassia extract, picrasmin, and parathion applied to the soil of potted plants were absorbed by the roots and translocated to the aerial parts, where they acted against some of the insects feeding thereon.

Mexican bean beetle larvae, *Epilachna varivestis* Muls., redheaded pine sawfly larvae, *Neodiprion lecontei* (Fitch), eastern tent caterpillars, *Malacosoma americanum* (Fitch), poplar tent maker caterpillars, *Ichthyura inclusa* Hbn., cowpea aphids, *Aphis medicaginis* Koch, a needle-feeding woolly aphid, *Unilachnus parvus* (Wilson), and the cabbage aphid, *Brevicoryne brassicae* (L.) were all affected by the quassia extract treatments. The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, the potato aphid, *Macrosiphum solanifolii* (Ash.), the green peach aphid, *Myzus persicae* (Sulz.) and the imported cabbageworm *Pieris rapae* (L.) were not affected by the quassia extract treatments.

The Mexican bean beetle and the eastern tent caterpillar were affected by the parathion treatments whereas the two spotted spider mites were not.

Several other chemicals were tested but were not found

to be effective as root-absorbed systemic poisons. These were: BHC, aloin, cyclohexanone oxime, 2,4-dimethyl-3-pentanone semicarbonzone, 4-phenyl-morpholine, alpha-ethyl-alpha-toluamide, 1 phenyl-2-propionylhydrozine, and 1-isobutyryl-2-phenyl hydrozine.

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Band Placement of Insecticides for Clover Root Borer Control[1]

C. R. WEAVER and J. L. HAYNES,[2] *Ohio Agricultural Experiment Station, Wooster*

The clover root borer, *Hylastinus obscurus* (Marsh.), has been an important insect on red clover for many years. Only recently, however, have insecticidal control measures been developed for this pest. App & Everly (1950) reported that BHC at the rate of 1.25 pounds of gamma isomer and aldrin at 2 pounds per acre in surface applications would control the root borer. Gyrisco *et al.* (1954) have reported investigations with various dosages of several insecticides. They reported that for consistent results with surface applications, 1 pound of toxicant per acre was required of aldrin, dieldrin, heptachlor, lindane, BHC, isodrin, or chlordane.

Many farms in the Midwest are now equipped to spray insecticides on field crops. Unfortunately low volume sprays have not given consistent results in controlling the clover root borer. Few farms have the necessary equipment for the application of dilute dusts. Furthermore, no presently available insecticide has given consistent results at less than 1 pound per acre. This dosage on a legume hay crop is pressing the limits of economic feasibility. The tests reported in this paper were conducted with the view of finding a method for control of the clover root borer that could be fitted to modern farm practices. In addition it was hoped that the efficiency of the insecticides could be improved so that the cost of their use would not be prohibitive.

Haynes & Thatcher (1950) developed a method of band seeding legumes. They modified a commonly used grain drill so that the legume seed would be placed directly over a band of fertilizer instead of being broadcast at random behind the drill. Because the seedling grew directly into the fertilizer band it received an initial start that gave it an advantage over seed not so placed. With this method, adequate stands could be obtained with less seed.

If root borer insecticides could be similarly placed, they would lie in the area of the root where the insect must work. This placement should result in increased efficiency of a given amount of insecticide per acre. With this idea in view, the following tests were conducted.

1951 TESTS.—In May of 1951, red clover was band seeded with 300 pounds of 0-20-10 fertilizer to which insecticides had been added. The per acre rates of insecticide used were BHC at 2.0 pounds of gamma isomer and aldrin at 0.25, 0.75, and 1.50 pounds. Plots band seeded with fertilizer containing no insecticide were included as checks. An individual plot measured three 8-foot drill rows wide and 90 feet long. Each of the three drill rows contained a different variety of red clover. Dollard, Kenland, and Midland were the varieties used. The various treatments were included in a randomized block design with four replications.

Although this experiment was designed as a root borer control test, data were also taken to show the effect on spittlebug infestation. Spittlebug control was evaluated on June 2, 1952 by counting nymphs per stem on 15 stems per plot. Root borer control was evaluated on July 15 by digging 15 roots per plot and determining whether or not they were infested or damaged by the root borer. Any root in which the damage was questionable was listed as damaged by a borer. First and second cutting yield data were taken on June 13 and August 13. A 7-foot mower swath was taken through the entire length of the plot. All the hay was weighed green, and samples were taken from each plot for dry matter determination. The data are reported as yield of 20% moisture hay. The data are presented in table 1.

The BHC treatment controlled spittlebugs and increased first cutting yields. All of the treatments controlled the clover root borer and increased the second cutting yields.

1952 TESTS.—In May of 1952 prior to obtaining the results of the above experiment, another band seeding of

[1] Accepted for publication December 6, 1954.

[2] Assistant Professor in Entomology and Professor in Agronomy, respectively.

Table 1.—Spittlebug and clover root borer infestations and yields of red clover band seeded with insecticides. Wooster, Ohio. 1952.

Insecticide lbs./A.	1st Cutting Yield, lbs./A.	Spittle-bugs Per Stem	2nd Cutting Yield, lbs./A.	Per Cent Borer Infested Roots
BHC, 2.0[a]	5,800	0.3	1,564	15
Aldrin, 1.5	4,700	5.4	1,376	10
Aldrin, 0.75	4,580	6.0	1,428	27
Aldrin, 0.25	4,540	5.1	1,264	33
Check	4,440	6.7	858	75
Yield L.S.D. 1%	484		270	

[a] Gamma isomer.

Table 2.—Clover root borer infestations and yields of red clover band seeded with insecticides. Wooster, Ohio. 1953.

Insecticide, lbs./A.	2nd Cutting Yield, lbs./A.	Per Cent Borer Infested Roots
BHC, 0.75[a]	2,740	7
BHC, 0.25[a]	2,180	31
Check	2,040	96
L.S.D. 5%	282	
Aldrin, 0.75	2,620	0
Aldrin, 0.25	2,680	5
Check	1,940	96
L.S.D. 5%	566	

[a] Gamma isomer.

Kenland red clover was made with 0-20-20 fertilizer containing aldrin. The rates of aldrin used were 0.25 and 0.75 pounds per acre. A check with fertilizer without insecticide was included. The plots were 24 by 60 feet, replicated three times in a linear Latin Square. In late June after the first cutting results of the 1951 seeding experiment were apparent, a test using BHC in place of aldrin was seeded. Exactly the same plot arrangement and dimensions as those in the May 1952 seeding were used.

Because of the small fall growth of clover and lack of stubble from a companion grain crop, spittlebugs were not present in large enough numbers to create an economic infestation. No differences in first cutting yields were evident and they are not reported here. Second cutting yields were taken on July 28 in the same manner as in the test above. Root borer infestation records were taken the same day in the manner described previously. In this case 45 roots per treatment were used. Presented in table 2 are the data obtained from these two experiments.

All of the treatments except the 0.25 pound rate of BHC gave satisfactory control of the root borer and increased the second cutting yield. All of the treated plots in this test showed substantially better recovery after the second cutting than the untreated checks. This factor may be important in increasing the value of the meadow as a green manure crop for the subsequent year.

SUMMARY.—Aldrin and BHC mixed with fertilizer and placed in a band under red clover seed gave good control of the clover root borer at substantially lower rates than are necessary for control by surface applications. Second cutting yields were increased from 34 to 82 per cent over untreated plots.

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The Distribution and Relative Abundance of Wireworms in Potato-Growing Areas of the Southeastern States[1]

O. T. DEEN and F. P. CUTHBERT, JR.,[2] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Wireworms are serious pests of many crops in the southeastern part of the United States. Their effect on the growth and market value of vegetables has become more apparent as the consuming public has demanded products of higher quality. The practice of washing root crops, especially potatoes, before shipment makes wireworm injury more visible.

Studies of the economic importance and distribution of wireworms in the coastal areas of the Southeast were begun at Charleston, S. C., in 1952 and are being continued. Thus far most of the work has been confined to species attacking potatoes. Similar studies made by Cockerham & Deen (1936) in southern Alabama and Mississippi between 1929 and 1936 served as a background.

Most of the species identifications were made by R. H. Arnett and M. C. Lane of adults that were either reared from larvae taken in potato fields or collected as adults in these fields or taken in an electric-light trap at Charleston. A few identifications were made by the authors.

Conoderus vagus CAND.—This wireworm, which at the outset was not known to be of economic importance

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[2] Under the supervision of W. J. Reid, Jr. Thanks are due M. C. Lane for his valuable suggestions pertaining to the manuscript.

in the United States and has no common name at present, was the species taken most frequently. It constituted 84 per cent of the 134 adults reared from wireworms taken from the soil in potato fields, 86 per cent of the specimens collected in 1954 as adults in or near potato fields, and approximately 92 per cent of 4,556 adults taken in the trap light.

The first report of its economic status in this country apparently is that of Dobrovsky (1953), who found that this insect is the chief economic wireworm infesting potato fields near Hastings, Fla. Lane (1953, 1954) published accounts of its history and distribution in the United States, based partly upon collections made by the authors. He reported that it evidently is a native of South America and that the first known record of its presence here is that of specimens taken by G. R. Pilate near Savannah, Ga., on May 12, 1927, and described by Fall (1929) as *Monocrepidius difformis*. It also was collected at Chadbourn, N. C., by J. N. Tenhet in June 1927, and at Florence, S. C., by O. L. Cartwright in October 1930.

In addition to Charleston and Beaufort counties of coastal South Carolina, it was collected in Bamberg, Colleton, Hampton, Florence, Orangeburg, and Williamsburg counties in the Coastal Plains, and in Laurens, Newberry, and Saluda counties in the Piedmont section of that State. The survey did not include more interior areas of South Carolina. Adults were taken in all the areas visited in North Carolina, which included the Coastal Plains counties of Brunswick, New Hanover, Pamlico, Beaufort, Hyde, Terrell, Martin, Craven, and Wayne. The infested sections included commercial potato-producing areas near Aurora and Columbia.

In Georgia adults were found in the coastal counties of Chatham and Camden and in the central and southcentral counties of Muscogee, Johnson, and Jefferson. This species was taken in about equal numbers with *amplicollis* in coastal areas, but appeared to be less abundant in the interior.

In northeastern Florida adults were readily found in home gardens in Duval County and in commercial potato fields in St. Johns County. They were also found in Leon, Gadsden, and Santa Rosa counties in north-central and northwestern Florida. Relatively few potato fields were seen in these areas. *C. vagus* appeared to be more abundant than *amplicollis* around Hastings and less so in the other areas.

In Alabama adults were abundant in commercial potato fields in Baldwin County on the Gulf coast. This wireworm was also abundant in similar fields in adjoining Escambia County. It also occurred in smaller plantings in Covington and Crenshaw counties in south-central Alabama. A few adults were taken in a home garden in Macon County in east-central Alabama. These records apparently are the first of its occurrence in Alabama. *C. vagus* now appears to be more abundant in the southern part of that State than *amplicollis*, which Cockerham & Deen (1936) found to be the chief wireworm pest of potatoes there between 1929 and 1936.

The senior author collected adults in 1930 in Harrison County in Mississippi and in 1934 in Terrebonne Parish in Louisiana.

M. C. Lane reported, in a letter dated September 13, 1954, that he had examined a large number of adults collected recently at New Orleans, La., and at Babson Park, Fla.

Conoderus amplicollis (GYLL.). (GULF WIREWORM).—Cockerham & Deen (1936) reported this wireworm, then known as *Heteroderes laurentii* (Guer.), as a destructive pest of potatoes in southern Alabama and Mississippi. Lane (1954) gave a brief history of the species and its known distribution, which includes the southeastern United States, Texas, and California.

The writers collected specimens in Brunswick County in southeastern North Carolina in 1953, this being the first record of its occurrence in that State. Three per cent of the 134 adults reared from larvae taken in potato fields in the Charleston, S. C., area and 14 per cent of the adults collected in these and nearby fields between 1952 and 1954 proved to be *amplicollis*. This species constituted about 4 per cent of 4,556 adults taken at Charleston in the electric-light trap during 1953 and through August 1954. It was taken in the same counties of South Carolina, Georgia, Florida, and Alabama as *vagus*, and probably is next to that species in economic importance as a potato pest. In general, it was more abundant than *vagus* in the interior of these States and less abundant in coastal areas. Adults were usually more numerous in corn fields and less so in potato fields than those of *vagus*.

Conoderus rudis (BROWN).—The senior author collected adults of this wireworm in 1930 along the Gulf coast in Mobile County in Alabama, and in Harrison and Pearl River counties in Mississippi. Adults were taken that year in Louisiana in Terrebonne Parish, and in 1942 in St. John the Baptist Parish. Adults were fairly abundant during May 1954 in Baldwin County in southern Alabama, apparently being about as numerous as *amplicollis*. A few adults were taken that year in a potato field in Escambia County and in a home garden in Macon County, Ala. According to Lane (1954), this species also appears to be a native of South America and is now known to occur only in the Gulf coast areas of Alabama, Mississippi, and Louisiana. Its economic importance and distinguishing larval characters are unknown.

Glyphonyx bimarginatus SCHFFR.—This species was taken by the senior author near Laplace, La., in 1942. It constituted 13 per cent of the adults reared from larvae found in potato fields near Charleston, S. C., and was collected in Tyrrell and Pamlico counties, N. C., and Bullock County, Ga. This wireworm was found feeding on potatoes, but in no case were infestations sufficiently high for it to be considered a major pest of that crop.

Conoderus vespertinus (FAB.).—This well-known species was found in all the areas surveyed. However, it was much more abundant in areas where tobacco or corn are the main crops than in those planted chiefly to truck crops. No larvae of this species have been identified from potato fields in Charleston County.

Conoderus lividus (DEG.).—This species was generally distributed over the areas surveyed, but only in small numbers.

Conoderus bellus (SAY).—Adults of this wireworm were abundant in all areas surveyed. The larvae are very small and have not yet been observed doing damage to vegetable crops in the Charleston area. Jewett (1940)

stated that this species feeds on corn and tobacco in Kentucky.

Colaulon rectangularis (SAY).—This species, the adults of which are sometimes called squareheads, was taken by the senior author in Harrison County, Miss., Baldwin County, Ala., and East Baton Rouge Parish, La., in 1930 and in Jackson and Santa Rosa counties in northcentral and northwest Florida in 1954. Adults were taken by K. L. Cockerham in Ware County, Ga., in 1934.

OTHER SPECIES.—In addition to the ones previously mentioned, the following Elateridae were taken in the electric-light trap operated at Charleston: *Conoderus auritus* (Hbst.), *C. aversus* (LeC.), *C. perversus* (Brown), *Dicrepidius corvinus* Cand., *D. ramicornis* Beauv., *Hemirhipus fascicularis* Fab., *Ischiodontus fuscus* (LeC.), *Megapenthes insignis* (LeC.), *M. rufilabris* (Germ.), *Melanotus divarcarinus* Blatch, *M. parallelus* Blatch, *M. secretus* (LeC.), *Orthostethus infuscatus* Germ., *Parallelostethus attenuatus* (Say), and *Hemicrepidius* sp.

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Pea Aphid Control with Demeton in Relation to Pea Plant Maturity[1]

J. W. APPLE and RONALD MARTIN,[2] *University of Wisconsin, Madison*

Demeton (a mixture of 0-[2-(ethylmercapto) ethyl]-0,0-diethyl thiophosphate and S-[2-(ethylmercapto)-ethyl]-0,0-diethyl thiophosphate) has been found to be an excellent aphicide under field conditions by numerous workers. Ashdown & Cordner (1952) demonstrated a high degree of pea aphid, *Macrosiphum pisi* (Harr.) control on garden peas with soil, seed and foliage treatments. Against the same insect on alfalfa, Davis & Swenson (1953) found a foliage spray containing 0.25 pound of demeton per acre to be the most effective of eight treatments. Reynolds *et al.* (1953) used 0.5 and 1 pound of demeton per acre on mature alfalfa plants against the pea aphid and found that both dosages all but eradicated the aphid for a 2-week period.

Wene & White (1952) found that 0.19 and 0.38 pound of demeton per acre gave better than 90 per cent cabbage aphid, *Brevicoryne brassicae* (L.), control for 8 days but after 14 days aphid populations had begun to rise quite markedly. Reynolds *et al.* obtained 98 per cent or better control of the cabbage aphid for 20 and 30 days with 0.5 and 1 pound of demeton per acre, respectively. Cabbage treated with 2 pounds of demeton to the acre remained relatively free of aphids for 70 days.

The turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis) was controlled for a 2-week period on turnips with demeton dosages of 0.19 and 0.38 pound per acre according to Dowdy & Sleesman (1952). These authors found the green peach aphid, *Myzus persicae* (Sulz.), and the potato aphid, *Macrosiphum solanifolii* (Ashm.) on eggplant highly susceptible to demeton at dosages ranging from 0.19 to 0.57 pound per acre. They reported this insecticide as having a rather prolonged life within eggplant. The green peach aphid was found by Reynolds *et al.* (1953) to be readily controlled on sugar beets with applications of demeton ranging from 0.55 to 1.4 pounds per acre.

The early work with demeton against aphids on vegetables indicates relatively low dosages are required on most crops to give satisfactory control but this toxicity is dissipated in 2 to 4 weeks depending upon the insect species, host plant and dosage employed. An experiment was undertaken with the pea aphid on canning peas in Wisconsin to determine whether adequate control of the insect could be obtained with decreasing dosages of demeton as crop maturity advanced. This approach to pea aphid control with a systemic insecticide might make it possible for a canner to eliminate the aphid and at the same time reduce the likelihood of having an excessive residue in the berries at harvest time.

METHODS.—A study such as this might be conducted on a single planting of peas by making insecticide applications to separate plots on different dates. This procedure, however, would subject demeton residues to unequal temperatures and thereby result in different rates of chemical degradation. For this reason the experiment was planned so that four dosages of demeton were applied on the same date to Wilt Resistant Perfection peas planted 18 to 54 days before treatment. The actual dates of planting were May 9, 23, June 2 and 14, with spraying taking place on July 2, 1953.

An emulsion concentrate of demeton (derived from Systox) containing 2 pounds of active ingredients per gallon was employed in making applications of 1, 2, 4, and 8 ounces of actual toxicant per acre. These dosages of demeton were applied to plants with small pods, plants at first bloom, and plants at 10 and 3 nodes, respectively. A standard treatment of 4 ounces of parathion was used on 10-node plants. Untreated plots for each plant maturity were included in the four replicate design. All

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[2] Professor of Entomology and Graduate Assistant in Chemistry, respectively.

Table 1.—Populations of the pea aphid on field grown peas of different maturity in relation to residues of demeton.

Days After Treatment	Plant Growth at Treatment and Ounces of Actual Toxicant per Acre											
	Small Pods One Ounce			First Bloom Two Ounces			10-Nodes Four Ounces				3-Nodes Eight Ounces		
	Aphids/Pan		P.p.m.	Aphids/Pan		P.p.m.	Aphids/Pan			P.p.m.	Aphids/Pan		P.p.m.
	Demeton	Check	Demeton	Demeton	Check	Demeton	Parathion	Demeton	Check	Demeton	Demeton	Check	Demeton
0		16.9			7.0				13.0			3.1	
(3 hrs.)			4.3			11.5				21.5			
1			4.3			10.3				19.5			
3	3.0[a]	40.2		0.1[a]	11.0		0.3[a]	0.0[a]	8.1		0.0[a]	2.5	
4			2.6			7.6				15.0			
6			1.4			5.5							
8	6.7[a]	37.1	0.4			3.9				9.5			14.0
10				1.2[a]	22.0		0.7[a]	0.5[a]	19.0		0.2[a]	3.7	
12						1.9				5.0			
15						0.5				2.8			
18				6.5[a]	28.1	0.3	18.0[a]	7.0[a]	55.7	1.5	7.5[a]	20.5	1.5
22										0.3			0.5
25							40.0[a]	23.8[a]	103.9		29.1	33.1	
26										Trace			0.3
31											104.6	86.3	
42													0.0

[a] Pea aphid population in treated plots significantly different from that found in control.

sprays were applied at the rate of 25 gallons to the acre with a small compressed-air sprayer.

Prior to treatment and at various intervals thereafter, pea aphid populations in the various plots were determined by the pan method. This procedure consists of jarring the aphids from two rows into a $4'' \times 14'' \times \frac{3}{4}''$ pan placed on the ground between the rows. Three such samples were taken per plot at each observation date.

Demeton residues within plants were determined at rather frequent intervals beginning with a reading 3 hours after treatment. Because of the very small plants and limited plot size, the plants receiving the 8-ounce dosage were not analyzed until 8 days after treatment. A 150-gram sub-sample of plant tissue (roots not included) was selected at random from a thoroughly mixed sample of plants taken from the four replicates of a given treatment for use in estimating the demeton residue. The analytical method followed was that of Giang & Hall (1951) which involves the measurement of cholinesterase inhibition resulting from the action of demeton or its degradation products.

As each planting matured, the peas were removed from the pods with a conventional viner and divided into two lots for processing. One group was frozen immediately after being washed while the second lot was washed, blanched and canned. Demeton residue determinations were made on both the frozen and canned peas by the authors and by the Pittsburgh Coke and Chemical Company.

Results.—As shown in table 1, the pea aphid populations were relatively low at the time of spray applications. However, on untreated plots of all four plant maturities, the aphids showed a steady increase in numbers up to the time of harvest. Three days after spray application, aphid populations were found to be reduced 92.5, 98.6, 100 and 100 per cent by the 1, 2, 4, and 8-ounce per acre dosages, respectively.

The first three reductions occurred on plants found to contain 4.2, 11.5 and 21.5 p.p.m. of demeton, respectively, 3 hours after treatment. Residues decreased quite rapidly and within 5 to 7 days only one-half of the original toxicant was found to be present in the plants. This marked reduction in toxicity as measured by cholinesterase inhibition, was evidenced by the fact that aphid populations were showing strong recovery within 8, 10, and 18 days on plants treated with 1, 2, 4, and 8 ounces, respectively. Demeton residues of approximately 2 p.p.m. were found in the plants of all plots at the time of these population increases.

Pea aphid control by the 4-ounce per acre dosage of demeton was not significantly different from that obtained with the standard treatment, 4 ounces of parathion. Parathion produced 96 per cent reduction of the aphids 3 days after treatment while the demeton caused complete elimination. However, aphids were present on the demeton treated plants 10 days after treatment and the aphid population rose thereafter at a rate comparable to that observed on the parathion treated plants.

Analyses for demeton residues in frozen and canned peas from the various plots, as shown in table 2, indicated that minute quantities were present, even in peas from the youngest planting which was harvested 42 days after treatment. The analytical method followed at the University of Wisconsin was not accurate below 0.3 p.p.m. and since all the findings in this laboratory were less than this quantity it was necessary to indicate the residues as

Table 2.—Demeton residues in canned and frozen peas following treatment for pea aphids.

Stage of Growth at Treatment	Dosage Ounces per Acre	Days from Treatment to Processing	P.P.M. Demeton in Peas			
			Frozen		Canned	
			Lab. 1[a]	Lab. 2[b]	Lab. 1	Lab. 2
Small pods	1	8	Tr.[c]	0.2	Tr.	0.1
First bloom	2	18	Tr.	0.2	Tr.	0.1
10-nodes	4	26	Tr.	0.3	Tr.	0.2
3-nodes	8	42	Tr.	0.0	Tr.	—

[a] Analyses by Department of Entomology, University of Wisconsin.
[b] Analyses by Pittsburgh Coke and Chemical Company, two months after Wisconsin analyses.
[c] Trace, or less than 0.3 p.p.m.

a trace. Duplicate samples assayed 2 months later by the Pittsburgh Coke and Chemical Company showed residues less than 0.3 p.p.m. because of refinements in their analytical procedure (Hensel *et al.* 1955).

DISCUSSION.—The attempt to find a dosage of demeton that would provide prolonged protection from pea aphids on pea plants of different maturity was not entirely successful. Plants within 3 weeks of harvest were protected with a single application of demeton but one treatment might not suffice on younger plants because of the rapid degradation of the toxicant within this species of plant. A single treatment on young plants might be satisfactory if aphid migration was not prolonged or if fungus disease acted to suppress the aphids as the plants matured.

SUMMARY.—Demeton was used for pea aphid control on canning peas at graduated dosages of 1, 2, 4 and 8 ounces per acre depending upon the maturity of plants. The 1-ounce dosage suppressed the pea aphid satisfactorily when the interval before harvest was no greater than 8 days. Peas, which were 18 days from harvest or just beginning to bloom at time of application, were protected from aphids for at least 10 days by an application of 2 ounces of demeton per acre. Dosages of 4 and 8 ounces per acre on peas at the 10-node and 3-node stages, respectively, gave excellent initial protection from aphids but 18 days later the aphids showed evidence of good survival. Treatment of young peas with demeton might necessitate retreatment before harvest under conditions of heavy aphid influx. Pea aphids reestablished themselves more slowly on plants treated with 4 ounces of demeton than on plants treated with an equal quantity of parathion, although these differences in population were not great enough to be significant.

Following application of the four dosages of demeton, frequent residue determinations were made by the cholinesterase-inhibition method. Three hours after treatment, the plants receiving 1, 2 and 4 ounces of demeton per acre showed residues of 4.3, 11.5, and 21.5 p.p.m., respectively. Because of the small size of plants, no analysis was made on plants receiving 8 ounces per acre until 8 days after treatment, when 14 p.p.m. of toxicant were detected. Residue analyses showed that only one-half of the original toxicant was present in the plants 5 to 7 days after treatment. Harvested peas which had been canned and frozen, contained residues amounting to less than 0.3 p.p.m.

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Safe Use of Dieldrin Dust for Sheep Ked Control[1]

R. E. PFADT, *Wyoming Agricultural Experiment Station, and* J. F. RYFF, *Wyoming State Veterinary Laboratory*[2]

Insecticidal dusting of sheep has become a widely used method of western ranchers to control infestations of sheep ked, *Melophagus ovinus* (L.). Experimentally, dieldrin dust has been found to be an effective material, but its external application to sheep has not been sanctioned chiefly because the amount of toxicant, if any, which might be taken into the animal's body through skin absorbtion or by other routes was not known. The primary reason for this study was to ascertain the extent of dieldrin residues in dusted sheep. A secondary objective was to make observations on the effect of dieldrin dust on the sheep themselves.

The study consisted of dusting sheep as would be done in controlling keds, sacrificing treated animals and untreated controls, making gross and microscopic examination for possible pathological changes, and analyzing sheep tissues for dieldrin.

METHODS.—Twenty fine-wool, white-faced ewes with lambs, reared and maintained at the Archer Substation, Wyoming, were gate-cut into two lots. Animals of one

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[2] The writers are indebted to the Shell Chemical Corporation, Denver, Colorado, for making the dieldrin analyses.

lot were treated twice with 1 per cent dieldrin dust, while animals of the second lot were retained as untreated controls. The two lots were run separately on pasture land to which no insecticide had been applied.

A Howry-Berg power sheep-duster was used to apply the dieldrin treatments. The first treatment was given on June 2, 1953, and the second 20 days later. In the first treatment, dust was expelled at the rate of 3.2 lbs. per minute and in the second at the rate of 2.4 lbs. Since sheep file through the dusting chute at an average rate of 33 per minute, the greatest average amount of dust that was possible for the sheep to receive was 0.17 lb. per head for the two treatments. This estimate is exaggerated since not all expelled dust adheres to sheep. An amount of 0.17 lb. of 1 per cent dieldrin dust applied to a 100-pound ewe is equivalent to 17 mg. of actual dieldrin per kg. of body weight; applied to a 30-pound lamb this amount is equivalent to 57 mg. of actual dieldrin per kg. of body weight.

At the end of the summer grazing period, 86 days after the final dusting, 5 treated ewes with their lambs and 5 untreated ewes with their lambs were sheared, sacrificed, and examined for pathology. Tissue samples of renal fat, omental fat, liver, and flesh were taken, packaged individually in plastic bags, and then frozen until analyses were made for dieldrin. Entire wool clips were also packaged individually in plastic bags and later analyzed for dieldrin. The materials for analyses were prepared by direct saponification and chromatography with magnesium oxide column. Analyses were made by the reduction-phenyl-azide photometric method which is specific for dieldrin (Shell Method Series).

The remaining 5 treated and 5 untreated ewes were discarded, but their lambs were placed separately into two feed pens and fattened 102 days as is normally done for market. The lambs were then sacrificed and treated as above.

In addition to the main group of sheep, 3 dry ewes were dusted twice and 3 maintained as controls. The dusting rates were 3 and 3.3 lbs. per minute, which was slightly higher than the dusting rates of the main group. All six sheep were slaughtered, examined, and tissues taken 9 days after the final dusting. Analyses for dieldrin were made by the microbioassay method described by Sun & Sun (1952).

RESULTS AND DISCUSSION.—Perceptible amounts of dieldrin were found in slightly more than half the samples of tissues taken from the three treated ewes slaughtered 9 days after the final dusting. Of the tissues analyzed, renal and omental fat contained the highest amounts, an average of 0.3 and 0.5 p.p.m. respectively; whereas liver and flesh contained the least amounts, an average of 0.04 and 0.07 p.p.m. respectively. No perceptible dieldrin was found in any of the tissues taken from ewes and lambs slaughtered 86 and 191 days after the final dusting (Table 1).

These results indicate that no hazards for human consumers accompany application to sheep of dieldrin dusts in amounts that effect control of sheep keds, if sheep are not slaughtered until 86 days after treatment. It is apparent, however, that some of the dieldrin applied to the surface comes to reside internally. Eventually these small amounts are lost, as all traces are gone by at least 86 days after treatment. This period of time is less than that required to bring lambs or cull ewes to market. Range sheep dusted in spring are marketed no earlier than fall, a period of about 120 to 150 days. Cull ewes may reach the packer for slaughtering at this time, but the lambs are placed in a feed lot for fattening and retained for approximately 100 days longer. If sheep were dusted in fall after marketing of lambs and cull ewes, the time interval between dusting and slaughter would be greater still.

Table 1.—Analyses[a] of sheep tissues after 2 treatments with 1 per cent dieldrin dust.

Tissue	Number Animals	Final Treatment to Slaughter (Days)	Dieldrin Found (P.P.M.)[b] Range	Average
Renal	3	9	<0.1–0.43	0.31
	10	86	all <0.1	<0.1
	5	191	all <0.1	<0.1
Omental fat	3	9	0.48–0.52	0.5
	10	86	all <0.1	<0.1
	5	191	all <0.1	<0.1
Liver	3	9	<0.1–0.11	0.04
	10	86	all <0.1	<0.1
	5	191	all <0.1	<0.1
Flesh	3	9	<0.1–0.21	0.07
	7	86	all <0.1	<0.1
	3	191	all <0.1	<0.1
Wool	10	86	<0.1–0.26	0.15
	5	191	all <0.1	<0.1

[a] Recovery of toxicant added to untreated samples at 0.1, 0.2, 0.3, or 0.6 p.p.m. was 70 per cent or over.
[b] Sensitivity of analytical methods: 0.1 p.p.m. "Less than" symbol indicates that no residues were detected at sensitivity of analytical method used.

Dieldrin was retained in the wool longer than in any of the internal tissues sampled. Six out of 10 fleeces had small amounts (0.1 to 0.26 p.p.m.) of dieldrin present 86 days after final dusting of the sheep. After 191 days no traces of insecticide were detected. There is little likelihood that residues of dieldrin would be present in wool at shearing time. Since sheep are usually dusted following shearing in spring as recommended (Pfadt *et al.* 1953), approximately 350 days would elapse before treated wool was shorn. If fall dusting after marketing were employed, approximately 180 to 235 days would intervene before shearing. The present tests have not definitely determined whether workers handling the pelts of slaughtered cull ewes could contact small amounts of dieldrin, as such ewes are slaughtered 130 to 150 days after spring dusting, a period midway between the times of finding small amounts of residue in the wool and none at all. However, it does not appear that this possible contact with dieldrin presents any hazard (Princi & Spurbeck 1950).

Examination of the carcasses of the mature sheep disclosed minor pathological changes in the organs of both treated and untreated sheep. These changes were within the range normally expected for aged animals of this species. Histological examinations of liver and kidney specimens revealed similar changes among animals of both groups.

Table 2.—**Pathological findings in lambs sacrificed after final dusting with dieldrin.**

LAMB	MACROSCOPIC LESIONS	HISTOPATHOLOGICAL FINDINGS
		After 86 Days
Control 1	Red hepatization of apical lobe of right lung. Spotted congestion of right lung.	Cloudy swelling of liver parenchyma. Kidney: one section normal; another some dilation of collecting tubules. Lung: over half of alveoli in section filled with red cells; numerous compact lymphoid foci present.
Control 2	Normal	Uniform cloudy swelling of liver parenchyma. Small irregular mononuclear focus in cardiac muscle.
Control 3	Normal	Cloudy swelling of liver parenchyma.
Control 4	Normal	Cloudy swelling of liver parenchyma.
Control 5	Normal	Cloudy swelling of liver parenchyma.
Dusted 1	Normal	Kidney: one section normal; second section two large cortical areas in which tubular epithelium and glomeruli are swollen.
Dusted 2	Normal	Cloudy swelling of liver parenchyma. Kidney: one section normal; second section dense, fibrous focus surrounding tubule.
Dusted 3	Diffuse necrosis over 1 by 4 inch area on peritoneal surface of liver.	Cloudy swelling of liver parenchyma. Kidney: one section glomerular tufts and tubular epithelium swollen over large area; second section intertubular foci of fibroblasts and glomerular tufts frequently swollen and densely cellular.
Dusted 4	Diffuse necrosis of liver over 1 by 2 inch area on diaphragmatic surface.	Cloudy swelling of liver parenchyma.
Dusted 5	Normal	Cloudy swelling of liver parenchyma. Kidney: one section normal second, tubular epithelium and glomerular tufts swollen over large area.
		After 191 Days
Control 1	Norma	Cloudy swelling of liver parenchyma.
Control 2	Normal	Cloudy swelling of liver parenchyma.
Control 3	Normal	Cloudy swelling of liver parenchyma.
Control 4	Normal	Cloudy swelling of liver parenchyma. Kidney: small lymphocytic focus in terminal collecting tubule.
Control 5	Normal	Cloudy swelling of liver parenchyma.
Dusted 1	Normal	Cloudy swelling of liver parenchyma.
Dusted 2	Normal	Cloudy swelling of liver parenchyma. One kidney normal; second with bluish casts in several small areas.
Dusted 3	Normal	Slightly cloudy swelling of liver parenchyma.
Dusted 4	Normal	Cloudy swelling of liver parenchyma.
Dusted 5	Normal	Cloudy swelling of liver parenchyma.

Pathological changes observed in the lambs are tabulated in table 2. Cloudy swelling of liver parenchyma was found consistently in both treated and untreated animals. Frequently this condition is seen in sheep and its presence in the control as well as the treated lambs indicates that it had no relationship to the dusting.

Two of the five dusted lambs which were sacrificed 86 days after treatment showed a diffuse necrosis of the liver. The livers of the remaining three showed no necrosis, nor did the livers of the five control lambs. Minor changes such as swollen tubular epithelium and glomerular tufts were found in the kidneys of the dusted sheep more often than in the untreated sheep. The significance of these differences between the two groups is not clear. In the light of other investigations referred to below it seems improbable that the differences were due to the effects of dieldrin. Additional study would be required to determine whether or not dieldrin in the amounts used causes pathological changes in kidney and liver.

The treated and untreated lambs sacrificed 191 days after dusting exhibited no deviations from normal with the exception of minor kidney changes found in one control and in one treated animal.

From experience gained in feeding dieldrin to rats and dogs (Treon *et al.* 1951, Kitselman 1953), no pathology due to application of small amounts of dieldrin externally should be anticipated in sheep sacrificed 86 or 191 days after treatment. Changes induced by administering sublethal doses of dieldrin orally to rats and dogs consisted of swelling of the cytoplasm and peripheral orientation of cytoplasmic granules in liver cells, fatty degeneration of liver cells, small focal areas of necrosis scattered through the liver, and parenchymatous degeneration in the cells of the kidney and brain. These changes were labile and affected tissues returned to normal after the animals were taken off dieldrin rations. In rats affected tissues returned to normal in 35 to 70 days.

According to Hayes *et al.* (1951) weight loss is the most nearly universal sign of dieldrin poisoning in various species of animals. In a study made by Pfadt *et al.* (1953), no significant differences in weight gains occurred between 35 lambs dusted twice with dieldrin (approximately 16 mg./kg.) and 35 untreated lambs. Both groups were fed the same fattening ration for 104 days. One lamb of the untreated lot died during the test, but none of the dusted lot died. This evidence indicates that growth of the lambs was not hindered by dusting with dieldrin. Radeleff (1950) found that 2-week-old lambs remained unaffected when sprayed with a 2 per cent emulsion of dieldrin (approximately 600 mg. of actual dieldrin per kg. of body weight). This rate of application is over 10 times the rate of dieldrin applied as dusts in the present tests and of that needed for control of sheep keds.

SUMMARY.—Dieldrin dust has been found to be a highly effective insecticide against keds on sheep, but it has not been sanctioned for external application chiefly because the amounts of residue which might come to reside in edible portions were not known. This investigation was undertaken to determine the residues of dieldrin in several sheep tissues resulting from dusting and to determine the effect of dieldrin dusting on the sheep themselves. Small amounts of dieldrin were found in renal fat, omental fat, liver, and flesh 9 days after treatment. Eventually these amounts were eliminated, as no traces could be found 86 days and 191 days after treatment. Wool retained dieldrin longer than the other tissues analyzed, as small amounts could be found 86 days after dusting but none 191 days afterwards. Evidence from this study indicated that no harm to sheep resulted from dusting with dieldrin, that consumers of lamb or mutton would not be endangered by residues of toxicant, and that wool would not contain any hazardous residues of dieldrin at shearing time.

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Insecticides against the Corn Earworm in New Brunswick[1]

D. D. POND,[2] *Field Crop Insect Section, Entomology Laboratory, Fredericton, N.B.*

The corn earworm, *Heliothis armigera* (Hbn.), occurs in some years in the province of New Brunswick, usually on fall fodder corn, although it has sometimes been early enough to attack late plantings of sweet corn. In 1947 the early sweet corn crop in New Brunswick was attacked for the first time on record. The presence of the insect was not detected until the first picking of sweet corn on August 11, when most of the larvae were full-grown. This infestation resulted in a loss of 55 to 90 per cent of the marketable ears.

TESTS IN 1947–48.—Preliminary tests were then conducted on the effectiveness of mineral oil injections (Barber 1944) and of 3, 5, 10 and 20 per cent DDT dusts in a 2½-acre block of mid-season corn near the center of the infested area. The DDT dusts were applied on August 14 and 18 and the mineral oil on August 14. A very light population of the earworm was noted to be already present before the insecticides were applied. Mineral oil gave 98 per cent of the ears free from injury; 3, 5, 10 and 20 per cent DDT dusts gave respectively 77, 92, 96 and 83 per cent, in comparison with 45 per cent in check plots.

Because of numerous objections to the mineral oil treatment (Bacon 1950) investigations in 1948 were conducted with dusts and sprays of several of the newer insecticides (Table 1). The experiment was conducted on a randomized block, each plot being 8 rows wide and 30 feet long and each treatment being replicated four times. The dusts were applied with a rotary hand duster at 40 pounds per acre and the sprays with a hand-pumped tank sprayer at 100 gallons per acre. Treatments were applied on August 16 and 24. On September 13 the two center rows of each plot were examined.

Five per cent DDT dust was highly significantly better than the rotenone dust or the check and significantly better than the rotenone or ryania sprays. Three per cent DDD dust was highly significantly better than the check and significantly better than the rotenone spray or dust. DDD, DDT spray and ryania dust were highly significantly better than the check, and chlordane spray and dust were significantly better than the check.

No experiments were undertaken in 1949 and 1950 owing to the entire absence of the corn earworm from the district.

Table. 1—Average percentages of worm-free ears of Golden Bantam sweet corn after application of various insecticides, Maugervillle, N. B. 1948.

TREATMENT	POUNDS TOXICANT PER ACRE	WORM-FREE EARS[a]
5% DDT[b] dust	2.0	92.5
3% DDD[c] dust	1.2	85.8
40% ryania[d] dust	16.0	79.6
50% DDD[c] (W.P.) spray	1.0	79.4
50% DDT[b] (W.P.) spray	1.0	78.2
5% chlordane[e] dust	2.0	73.7
40% chlordane[e] (W.P.) spray	1.0	66.6
100% ryania[d] spray	4.0	61.7
0.5% rotenone[b] spray	0.2	57.2
0.5% rotenone[b] dust	0.2	51.0
Untreated		32.0

[a] Arc sign transformation difference necessary for significance at 1% level: 26.43 at 5% level: 19.60.
[b] Canadian Industries Ltd., Montreal, Que.
[c] Rohm & Haas Co., Philadelphia, Pa.
[d] Merck & Co., Montreal, Que.
[e] Julius Hyman & Co., New York, N. Y.

TESTS IN 1951–52.—In 1951 dusts only were tested, on plots 1/10 acre in size laid out in a latin square design. Because 5 per cent DDT dust was not readily available, a 3 per cent DDT dust was substituted. Only one application was made, on August 15; a second scheduled application was not made because of a long period of inclement weather. Three per cent DDD dust gave better control than 3 per cent DDT, 40 per cent ryania, or ryania plus a synergist, the differences being highly significant (Table 2).

In 1952 plot size and design were similar to those used in 1951. The following dusts were applied: 3 per cent DDT; 40 per cent ryania; ryania plus a synergist (Ryanexcel) and 3 per cent DDD at the rate of 40 pounds per acre. The first dust was applied on August 20, when earworm eggs were first noted. The second dust was delayed until August 29 because of weather conditions.

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[2] Acknowledgment is made to Mr. R. C. Sherwood, of Canada Packers Ltd., Saint John, N. B., who, while on the staff of the Entomology Laboratory, Fredericton, conducted some of these experiments and assisted materially in securing data and preparing this paper.

Table 2.—Average percentages of worm-free ears of Golden Bantam sweet corn after application of various dusts, Maugerville, N. B. 1951.

TREATMENT	POUNDS TOXICANT PER ACRE	WORM-FREE EARS[a]
3% DDD[b]	1.2	88.7
3% DDT[c]	1.2	23.7
40% ryania[d]	16.0	17.9
Ryania+synergist[e]	6.0	7.2
Untreated		4.3

[a] Arc sign transformation difference necessary for significance at 1% level: 31.72 at 5% level: 22.66.
[b] P. N. Soden and Co., Montreal, Que.
[c] Canadian Industries Ltd., Halifax, N. S.
[d] S. B. Penick and Co., New York, N. Y.
[e] Ryanexcel, 15% ryania+0.5% *n*-propyl isome+84.5% inert ingredients, S. B. Penick and Co., New York, N. Y.

The earworm infestation was uniformly severe, most of the ears containing two or more larvae. None of the treatments gave an economic control. These results agree with those of Bacon (1950) and others who reported that dust treatments are not effective against heavy earworm populations.

SUMMARY.—In New Brunswick, the corn earworm does not appear every year. When a light to medium infestation does occur it may be satisfactorily controlled with mineral oil, 5 per cent DDT dust, 3 per cent DDD dust or 40 per cent ryania dust. A single application of 3 per cent DDD dust gave significant control of a heavy population in 1951. However, two applications of this dust against a heavy population in 1952 failed to give economic control.

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Preliminary Experiments in Corn Earworm Control[1]

JOHN H. HAWKINS, *Maine Agricultural Experiment Station, Orono*

The corn earworm, *Heliothis armigera* Hbn., has caused extensive injury to the sweet corn crop of southwestern Maine for a long time. Now corn earworms frequently infest corn ears wherever corn is grown. Consequently corn growers generally are seeking a practical method of controlling earworms. It is likely that most infestations in Maine have their origin in flights of the adult moths from areas to the south and west of Maine; therefore insecticidal control seems to be the logical approach in the prevention of the excessive losses now caused to the corn crop by earworms.

A review of the literature on corn earworm control reveals numerous publications reporting results of investigations covering many years. Only a few can be cited here. Butler & Carruth (1949) reported a single application of DDT in mineral oil to be effective for corn earworm control. According to Hayslip *et al.* (1953, p. 577), "The use of mineral oil with DDT emulsion resulted in a larger percentage of worm-free ears than when the DDT emulsion was used alone." Howe & Davis (1954, p. 97) found that "Mineral oil increased the efficiency of DDT sprays, especially under cool, rainy conditions." The literature on corn earworm control in general shows that DDT is a promising corn earworm insecticide.

MATERIALS AND METHODS.—Preliminary investigations concerning insecticidal control of corn earworms were initiated in 1954. A field was divided into two parts. Sweet corn variety Golden Jewell was planted in part one on June 18 and Seneca Golden sweet corn was planted on June 17 in part two.

Insecticides were applied as dilute spray and the rate per acre was 150 gallons for all mixtures included in the experiment. DDT insecticides were used at the rate of 2 pounds of actual DDT to make a finished spray of 150 gallons. Individual spray mixtures were as follows: (1) DDT emulsion; (2) DDT emulsion plus 2½ gallons of white mineral oil, viscosity 60 to 90; (3) DDT wettable powder combined with ½ pound of a surfactant to each 150 gallons of finished spray, and in part one an additional spray, (4) 1½ quarts of a combination of 10 parts of piperonyl butoxide to 1 part of pyrethrins in water to make 150 gallons of the finished spray mixture.

The spray applications were made with a high-clearance, row-crop sprayer maintaining a pressure of approximately 300 pounds per square inch. Three spray nozzles were directed to each row so that the spray was concentrated on the corn ears.

The corn planted in part one of the experiment was divided into plots to form a 5×5 replicated Latin square. The plots in part two were arranged in a 4×4 replicated square. In all cases treatments were two rows wide and 45 feet in length and contained approximately 1/160 of an acre.

Corn earworm eggs were found in part one on August 16 when approximately 10 per cent of the corn ears were in silk. Three spray applications beginning on August 17 were made at 3-day intervals. Cool, rainy weather persisted throughout the summer and until after harvest in September.

RESULTS.—The number of earworms in the untreated plots was significantly higher than in any of the treatments, covered in Part I of table 1. There was no significant difference in the number of earworms found in each of the three treatments containing DDT. The number of earworms in the plots receiving the piperonyl butoxide-pyrethrins insecticide was significantly higher than the

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Table 1.—Control of corn earworm in Maine.

Treatment	Earworms	
	Number	Per Cent Reduction
Part I (Five replicates)		
DDT—Emulsion	16	93.7
DDT—Emulsion and Mineral Oil	19	92.5
DDT—Wettable and Surfactant	19	92.5
Piperonyl Butoxide and Pyrethrins	66	74.1
Untreated	255	
Part II (Four replicates)		
DDT—Emulsion	9	84.7
DDT—Emulsion, Mineral Oil	6	89.7
DDT—Wettable Powder and Surfactant	23	61.6
Untreated	59	

percentage of earworms found in all treatments containing DDT.

The number of earworms found in the untreated plots, in Part II, of table 1 was significantly higher than the number found in treated plots. The number of earworms found in the ears harvested from plots receiving treatment with DDT-wettable powder, was significantly higher than from the DDT-emulsion treatments. Insecticides listed in Part II were applied on August 24, 27, and 30.

The results recorded in table 1 show that the DDT emulsion and the DDT emulsion with mineral oil sprays, as used in these experiments are reasonably effective against the corn earworm. However, the degree of earworm control obtained from DDT emulsion and DDT emulsion plus mineral oil used as dilute water sprays in Part I were on the average, 5.9 per cent more effective than were the same formulations as recorded in Part II of table 1.

On the other hand, DDT wettable powder containing a wetting agent and applied as a spray in Part I was 34.6 per cent more effective than was exactly the same spray when used in Part II of these tests. These limited data indicate that DDT wettable powder may be less dependable in corn earworm control than is the DDT emulsion or the DDT emulsions containing mineral oil.

Since there was some variation in results obtained with the same materials used in Part I and Part II certain factors affecting this experiment should be stated. Excessive moisture and cool weather prevailed throughout the season. Corn earworm populations in the first test were considerably greater than in the second. About 5½ inches of rain fell on September 11 after the ears were harvested in the first test but had not yet been harvested in the second. There was no evidence of injury to any part of the corn plants by the insecticides applied in these tests.

Relation of European Corn Borer Control to Corn Earworm Abundance.—A local opinion occasionally voiced in central Maine is that DDT applied for European corn borer control should also control the corn earworm. At various times while dissecting corn plants for European corn borers more earworms were found in plots treated with DDT for control of the European corn borer than in the untreated plots. In 1953 data on earworm populations were recorded at the time when the corn was harvested in the European corn borer experiments. Corn ears in 32 out of a total of 80 plots located in one section of the field were found to be infested by earworms. In this area all of the treated plots were sprayed with DDT wettable powder at the rate of 2 pounds of the active ingredient per acre, and there was an average of twice as many earworms as there was in the untreated plots. The average number of European corn borers recorded in the check plots of this area was approximately 7½ times that recorded in the treated plots.

In 1954 a preliminary experiment was set up to study the possible relation of European corn borer control to corn earworm abundance. Plots were replicated six times and the insecticides were applied on July 27 and August 30. The results are given in table 2.

The number of corn earworms (186) found in the plots treated with DDT emulsion is significantly higher at the 1 per cent level than the 118 earworms found in the untreated plots. The 131 earworms found in the plots treated with DDT wettable powder is significantly higher at the 5 per cent level than the number of earworms found in the untreated plots. In direct contrast the nine European corn borers found in the plots treated with DDT emulsion is significantly lower than the number of borers found in the untreated plots. No correlation could be proven between the low number of European corn borers and the high number of earworms.

More extensive data are needed before a definite conclusion can be reached, although the fact remains that corn treated with DDT emulsions in late July and early August (where European corn borers were fairly well controlled) there were more corn earworms at harvest time than there were in the untreated plots. If these data are confirmed by further experimentation, it will be more important than ever to evaluate the danger of injury by the European corn borer as compared with that caused by possible increases in corn earworm populations. Results of this evaluation should be considered before applying DDT for European corn borer control.

Summary.—DDT emulsion and DDT emulsion containing mineral oil were effective in controlling earworms.

Piperonyl butoxide-pyrethrins was somewhat less effective than DDT but may have a limited use where DDT residues would be objectionable.

Results were inconclusive in experiments designed to

Table 2.—Effect of treatments for control of the European corn borer on populations of the corn earworm.

Treatment	Corn Earworm		European Corn Borer	
	No.	Increase in Number	No.	Decrease in Number
DDT Emulsion	186	68	9	22
DDT Wettable Powder and Surfactant	131	13	17	14
Untreated	118			

compare the effectiveness of DDT emulsion plus mineral oil with DDT emulsion alone.

DDT wettable powder was about equal in effectiveness to DDT emulsion formulations applied in one test whereas in another it was less effective.

Data obtained in preliminary investigations indicate a possibility of increases in earworm populations in corn sprayed with DDT in late July or early August for control of the European corn borer.

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Tests with Some Phosphorus Compounds against Cattle Grubs[1]

A. R. ROTH and GAINES W. EDDY, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The spray recommended and widely used for the control of cattle grubs, *Hypoderma bovis* (L.) and *lineatum* (De Vill.), consists of a suspension of 7½ pounds of cube or derris powder (5% rotenone) in 100 gallons of water. As a wash 12 ounces of this powder per gallon of water is used.

Various rotenone formulations have been used against cattle grubs for more than 20 years. Many new insecticides have been tested during the last few years, but none proved very effective until Smith & Richards (1954) showed certain phosphorus compounds to be promising as washes against larvae of *lineatum*. Preliminary tests with some of these and certain other materials were made by the authors as washes and as sprays at Corvallis, Oreg.

TESTS WITH WASHES.—Three Bayer compounds were tested as washes—21/199, 21/200, and L 13/59 and also chlorthion. The wettable powders were commercial preparations except for 21/200, which was formulated by the authors from the technical grade. The emulsion concentrates and aqueous solutions were also prepared in the laboratory.

Most of the animals used in the tests were Herefords, yearlings or older, although some were Jerseys, Holsteins, or mixtures of these breeds. The insecticides were thoroughly scrubbed into the backs with a stiff brush at the rate of 1 pint per animal. The number and instars of the larvae present in the animals were recorded before treatment, and mortality counts were taken after 1, 2, and sometimes 3 weeks. The results of the tests with the materials applied as washes are presented in table 1.

Table 1.—Effectiveness of some phosphorus compounds against *Hypoderma lineatum* when applied as washes to the backs of animals.

Formulation	Per Cent Concentration	Number of Larvae		Per Cent Mortality After—		
		Second Instar	Third Instar	1 Week	2 Weeks	3 Weeks
Bayer 21/199 50% W.P.	1.0	6	14	100	—	—
		3	5	100	—	—
	0.5	0	5	100	—	—
		2	8	—[a]	100	—
		1	12	—[a]	100	—
	0.25	3	17	—[a]	—[a]	80
	0.1	2	5	0	0	0
20% Emul.	0.5	9	6	—[a]	100	—
Bayer 21/200 50% W.P.	1.0	7	8	—[a]	100	—
		0	16[b]	100	—	—
	0.5	0	12[b]	100	—	—
	0.25	0	4[b]	0	50	—
Bayer L 13/59 50% W.P.	1.0	2	19	95	100	—
Aqueous solution	1.0	3	34	100	—	—
	0.5	0	22	0	0	91
	0.1	1	5	0	0	0
Chlorthion 50% Emul.	5.0	0	30	0	0	43
	3.0	0	18	0	0	33
	1.0	1	13	7	14	14
	0.5	6	1	71	71	71
25% W.P.	1.0	4	4	—[a]	62	62

[a] Partial.
[b] *Hypoderma bovis.*

Bayer 21/199.—This material was tested at 1.0, 0.5, 0.25, and 0.1 per cent. Complete kill of the larvae was caused by the two highest concentrations. The material was distinctly more rapid in its action at 1.0 than at 0.5 per cent. All the grubs in the two animals treated with 1.0 per cent died during the first week after treatment. Some of the larvae in three of the four animals treated with the 0.5 per cent preparation were alive after 1 week, although all were dead by the end of the second week. This conpound appeared to be more effective in these tests than in those conducted by Smith & Richards (1954).

Bayer 21/200.—Four animals were treated with this compound, three of them late in the season when they were infested only with *bovis*. The material caused complete kill of the larvae at 1.0 and 0.5 per cent but not at 0.25 per cent. The results were similar to those obtained with 21/199.

Bayer L 13/59.—This material was applied to two animals at 1.0 per cent and to one each at 0.5 and 0.1 per cent. Triton X-100 at 0.25 per cent was added to the aqueous solutions to improve their wetting properties. All the larvae were killed at 1.0 per cent but not at lower concentrations. At 0.5 per cent there was no kill during the first 2 weeks, but 91 per cent died between the second and third weeks after treatment. The results indicate that the material is somewhat less effective than either

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21/199 or 21/200. In similar tests Smith & Richards (1954) reported 88 per cent kill with 1.0 per cent of L 13/59.

Chlorthion.—Chlorthion was tested at 1.0 per cent in a wettable-powder suspension and at five concentrations ranging from 0.5 to 5.0 per cent as an emulsion. None of the treatments killed all the larvae over a period of 3 weeks.

TESTS WITH SPRAYS.—Only Bayer 21/199 and rotenone were tested as sprays. The tests were made against *bovis* larvae present in the backs of Hereford cattle. Bayer 21/199 was tested at 0.5 per cent and 0.05 per cent of Gardinol, a wetting and disbursing agent, was added to improve its stability and wetting properties. Approximately 1 gallon of the spray was applied to each animal at 350 pounds' pressure. The spray gun was held at right angles to and approximately 12 inches from the backs of the animals.

Nine animals treated with Bayer 21/199 had 15 second- and 70 third-instar larvae or a total of 85. Thirty animals treated with the standard rotenone spray had 40 second- and 205 third-instar larvae, or a total of 245.

Bayer 21/199 killed all the larvae during the first week. Rotenone caused 84 per cent mortality after 7 days and 91 per cent after 14 days. Bayer 21/199 at 0.5 per cent appeared to be more effective and more rapid in its action than the standard rotenone spray. The material was also somewhat more effective as a spray than as a wash. However, rotenone has also been shown to be more effective as a spray than as a wash (Snipes *et al.* 1948). Lofgren *et al.* (1954) showed their highest kill with washes was 92 per cent but 98 per cent with sprays.

The importance of the effectiveness of these new insecticides is indicated by the fact that complete kill of grub larvae is rarely obtained with rotenone, regardless of the method of application.

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Two Items of Equipment Useful in Black Fly Larval Control[1]

ARDEN O. LEA, JR., *Laboratory of Tropical Diseases, National Microbiological Institute,[2] Bethesda, Maryland*

METAL CANAL FOR VOLUME DETERMINATION OF SMALL STREAMS.—During the course of field experiments on the larval control of black flies, *Simulium* spp., in Guatemala, Central America, it was necessary to make volume determinations of over 1,000 small streams and rivulets. These streams ranged between 10 and 100 gallons per minute flow and were important black fly breeding places. As a prelude to a larviciding program several teams of workers were sent out daily to survey and record the volume of each tributary entering a particular large main stream. Later, when larviciding was actually under way and the area to be treated was being expanded, each tributary was treated as soon as its volume had been determined. Because of the large number of streams to be treated, speed in making the volume determinations was essential. The terrain was mountainous and rugged, so that equipment transported to the field had to be kept to a minimum.

Because the small breeding streams were often filled with debris and trailing leaves, and were shallow and winding, the methods of volume determination usually employed in the larger streams were impractical. To overcome this problem a small portable metal canal was devised with which field crews could make rapid and direct volume determinations of streams under 120 gallons per minute flow.

The canal (Fig. 1) was 12 inches wide at one end, narrowing to a width of 5 inches at the other. The narrow end was blocked by a piece of wood having a u-shaped cut-out 2 inches wide and extending from the top to within 1½ inches of the bottom of the canal. The canal was simply used as a means of channeling all the water from the stream and forcing it to pass through the u-opening at the lower end. This restricted outlet had a damming effect which caused the water to rise in the canal, the pressure of the stream flow maintaining this rise. Centimeter graduations at the sides of the u-opening enabled the operator to measure the height of the water's rise. The graduations had previously been calibrated as flow in gallons per minute by collecting the water emitted by the canal at each centimeter mark for a 1-minute period. Thus, direct field determination of volume could be made easily and quickly at each stream. The range of the canal was limited by the size of the u-opening and the height of the sides. The ones contructed for the work in Guatemala were adequate for streams from 10 to 120 gallons per minute.

FLOATING SIPHON LARVICIDE DISPENSER.—In certain

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[2] National Institutes of Health, Public Health Service, U. S. Department of Health, Education, and Welfare.

FIG. 1.—Metal canal for volume determinations in small streams: Water of stream channeled into canal rises as it flows through u-opening. Height of rise in centimeters read as gallons per minute flow. Volume of stream shown 35 gallons per minute.

field experiments it was necessary to treat streams ranging in volume from 1,000 to 10,000 gallons per minute for a period of 60 minutes. The larvicide, transported to the streams as emulsion concentrate, was diluted with water to a total volume of 3 to 4 gallons. Again, all equipment for dispensing the toxicant had to be minimal and simple in construction.

Although an ordinary siphon was preferable to hand pouring the larvicide, it did not dispense the material at an even rate, the flow from the siphon being fast at the start and gradually slowing as the level of the liquid lowered. In order to overcome this disadvantage, a "floating siphon" was designed to empty a 5-gallon can of diluted larvicide in 60 minutes.

The "floating siphon" (Fig. 2) consisted of a piece of plastic tubing, one end of which was inserted into a large cork. A piece of stiff wire fastened in the bottom of the can projected up inside the tubing to act as a guide, keeping the siphon upright as the cork floated on the liquid. A lead sinker attached to the cork helped to counterbalance the weight of the outer arm of the siphon, and also served as a weight to overcome the friction between the wire guide and the plastic tube of the siphon. Because the siphon intake lowered at the same rate as the liquid level in the can, the pressure always remained constant and the flow even, during the entire treatment period. The rate of delivery could be checked with accuracy by collecting the output from the siphon in a graduate cylinder for a 1-minute period. The rate of flow could be adjusted by lengthening or shortening the siphon outlet. Thirty minute treatments were made using half the volume of liquid needed to dispense the material for a 1-hour treatment.

This proved to be a very convenient and satisfactory means of making larvicide applications to the test streams for extended periods.

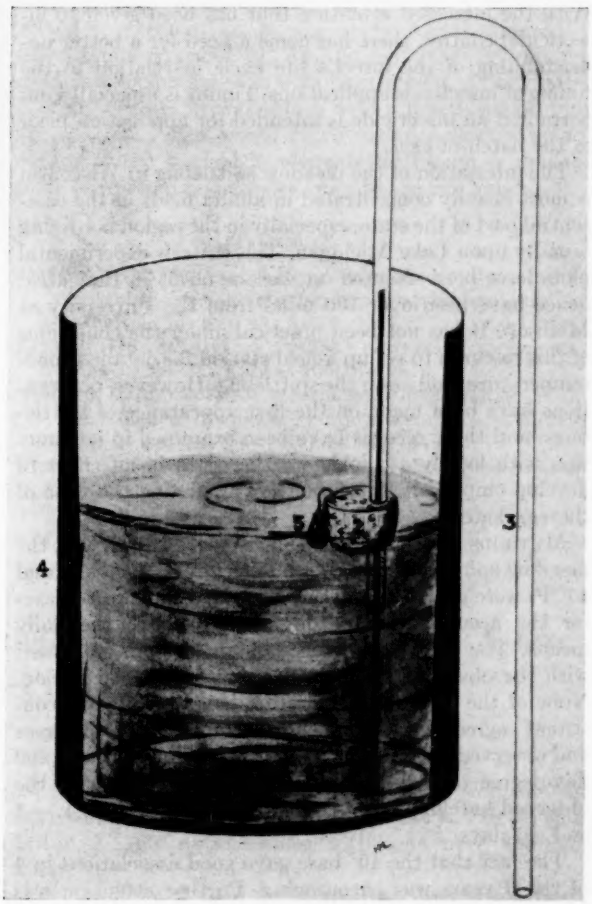

FIG. 2.—Floating Siphon Larvicide Dispenser: 1—Stiff wire guide fastened to bottom of can and projecting up inside siphon. 2—Cork, siphon tube off-center for counterbalancing. 3—Plastic tubing (bent to "U" shape in boiling water). 4—Five-gallon can. 5—Lead sinker as counterbalance for outer arm of siphon and weight to overcome friction of wire inside siphon during lowering.

Method of Predicting the Hatching Date of the Meadow Spittlebug[1]

J. T. Medler[2]

In recent years entomologists have done considerable research on the meadow spittlebug, *Philaenus leucophthalmus* (L.). For example, a bibliography of the literature on this insect by Weaver & King (1954) contains over 500 citations, of which at least 200 have appeared since 1945. Most of the recent articles have been concerned with control tests with insecticides in North America. With the increased attention that has been given to insecticidal control, there has come a need for a better understanding of the insect's life cycle in relation to the timing of insecticide applications. Timing is especially important if an insecticide is intended for application prior to the hatch of eggs.

The infestation of the meadow spittlebug in Wisconsin is most heavily concentrated in alfalfa fields in the east-central part of the state, especially in the region bordering broadly upon Lake Michigan. The writer's experimental plots have been situated on various farms in that area; hence have been over 100 miles from the University at Madison. It has not been practical under the conditions of this research to set up a field station for detailed time-temperature studies on the spittlebug. However, observations have been made on the first appearance of spittlebugs, and these records have been examined in conjunction with locally available weather data in an effort to develop empirically a method for predicting the time of the egg hatch.

Methods and Results.—Since it was known that the meadow spittlebug is a cool-season insect, 40°, 43°, and 45° F. were arbitrarily selected as the temperature bases for the accumulation of day-degrees above the daily means. The total day-degrees obtained were compared with the observed hatching dates over a 6-year period. None of the selected temperature bases resulted in consistent agreements between accumulated day-degrees and observed hatching dates, but it was found that a 200 day-degree total using the 40° base coincided with the observed hatching dates as follows: −2, −2, 0, +4, −1 and +7 days.

The fact that the 40° base gave good associations in 4 of the 6 years was encouraging. Further attention was given to the temperature data in 1952 and 1954, which were the years when the plus factor existed. It was found that in 1952 an unusual period of warm weather had occurred between April 17–22, during which the average daily accumulation was 19 day-degrees; and that 1954 also had an early warm period during April 10–21 when the average daily accumulation was 14 day-degrees. Therefore, it was postulated that high temperatures were retarding the hatch of spittlebug eggs, and that the accumulations should be "corrected" for this factor.

In making the correction the 40° base was used, and maximum temperatures above which the day-degrees were not added to the accumulations were tried at 50°, 55° and 60° F. The "corrected" accumulations were compared with the observed hatching dates, and it was found that a much improved association could be made between the day-degree total and the observed hatching dates in the years 1952 and 1954, whereas the agreements in the other 4 years were not substantially changed. Best agreements were found with the 50° correction, which was to be expected, since very few days in the period of spring preceding the spittlebug hatch have a daily mean temperature above 55 to 60° F. For the 6-year period the total day-degrees at the observed hatching dates which were calculated from the daily mean temperatures between 40° and 50° F. were as follows: 173, 179, 192, 171.5, 172 and 198.

Table 1.—Deviations of observed hatching dates of the meadow spittlebug from dates of 150 day-degree accumulation (40°–50° F.) at Plymouth, Wisconsin, 1949–1954.

Year	Observed Hatching Date	150 Day-Degree Accumulation Date	Days Deviation
1949	May 3	May 1	+2
1950	May 17	May 14	+3
1951	May 13	May 8	+5
1952	May 1	April 29	+2
1953	May 11	May 9	+2
1954	April 30	April 24	+6

The final step in the development of the method was to select a day-degree total which would precede the observed hatching dates and allow a prediction of the egg hatch. An 150 day-degree total was chosen. Data are given in table 1 which show that predictions deviating from the observed hatching dates by from 2 to 6 days were made during the 6-year period.

Discussion.—The writer is aware of the classical methods of conducting research on time-temperature relationships in insects, including the investigations of Shelford (1927). It might have been desirable to have had developmental units and velocity of development curves for the spittlebug, and such information no doubt would have allowed a more precise selection of the temperature bases. However, it is believed that the microclimate precision of the laboratory can be reconciled with empirical macroclimate practices in the field, and the latter is an especially logical approach if temperature data are to be obtained from local weather bureau stations.

Barnard (1948) has reported that heat unit summations are of practical value in the planting and harvesting management of canning crops. Apple (1952) described a method of following the seasonal development of the European corn borer by the use of "borer day-degrees," which were obtained by summing the degrees above 50° F. It appears from the above data that the accumulation of "spittlebug egg day-degrees" provides a practical method for the prediction of the egg hatch.

In order to test the method, the hatching dates at two Ohio stations, which were published by Weaver & King (1954), were analyzed. The Ohio temperatures were obtained from Climatological Data published by the U. S. Weather Bureau. The accumulations are given in table 2. It was found that in only 3 of 11 years would the prior

[1] Accepted for publication December 21, 1954.

[2] Associate Professor, Departments of Agronomy and Entomology, University of Wisconsin, Madison.

Table 2.—**Deviations of observed hatching dates of the meadow spittlebug from dates of 150 day-degree accumulations at two localities in Ohio.**[a]

	Columbus			Wooster		
Year	Observed Hatching Date	150 Day-Degree Accumulation Date	Days Deviation	Observed Hatching Date	150 Day-Degree Accumulation Date	Days Deviation
1948	April 10	March 31	+10	—	—	—
1949	April 11	April 11	0	April 19	April 13	+6
1950	April 18	April 22	−4	April 27	April 26	+1
1951	April 20	April 15	+5	April 20	April 19	+1
1952	April 16	April 13	+3	April 16	April 18	−2
1953	April 9	April 3	+6	April 9	April 10	−1

[a] Hatching dates taken from Weaver & King (1954) and temperature records from U. S. Weather Bureau Climatological Data.

prediction of the egg hatch have been missed. It might be expected that some discrepancies would occur in regions where the climate is not moderated by a lake shore environment, but it is also possible that the selection of a different correction factor would improve the reliability of the Ohio predictions. It should be mentioned that the accumulations in table 2 were started in February and it may be necessary to allow for the development of the embryo which may take place in the fall in Ohio, according to Weaver & King (1954, p. 39).

The main purpose in the development of the prediction method was to allow better planning of insecticide applications, particularly the use of granulated formulations intended for application prior to the egg hatch. Under Wisconsin conditions the method is sufficiently accurate for that purpose. By the routine use of the accumulations and judgment regarding the seasonal trends, it has been possible to make applications of insecticides just prior to the egg hatch. The method has been particularly helpful to the writer, since the 150 day-degree accumulation at Madison precedes that total in the area of spittlebug research, and plans could be made accordingly.

SUMMARY.—The empirical development of a method to predict the hatching date of eggs of the meadow spittlebug is described. An accumulation is made of the day-degrees above a daily minimum mean temperature of 40° F., corrected to exclude the degrees above a maximum daily mean temperature of 50°, i.e., no more than 10 day-degrees are accumulated in a 24-hour period. At a total of 150 day-degrees, it was shown over a 6-year period that the spittlebug eggs would hatch within a week. The accuracy of the method is adequate for planning applications of residual insecticides prior to the egg hatch.

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Comparative Toxicity of Some Insecticides to Peregrinus maidis (Ashm.) and its Egg-Predator[1]

JIT SINGH VERMA,[2,3] *University of Hawaii, Agr. Expt. Sta., Honolulu*

The failure of biological control agents, especially the egg-predator, *Cyrtophinus mundulus* (Bredd.), to effect commercial control of *Peregrinus maidis*, the corn leafhopper, in Hawaii, necessitates the use of insecticides. *C. mundulus* is of great economic importance. It keeps the population of *Perkinsiella saccharicida* Kirk., the sugarcan leafhopper, below the economic threshold. *C. mundulus* also has some beneficial role in checking the growth of the corn leafhopper populations in the later stages of corn growth. Laboratory studies were conducted in order to find out the comparative toxicity of several common insecticides used against the pest and their effect on the predator.

Studies on the chemical control of *Peregrinus maidis* have been made by several workers. Swingle & Mayer (1944) conducted laboratory tests with DDT and found that a 5 per cent dust was enough to cause 100 per cent mortality of "large numphs" within 24 hours. Brooks & Anderson (1947) found little difference in the effectiveness of BHC dust (one per cent gamma isomer), 3 per cent DDT or 5 per cent chlordane in pyrophyllite, used the field.

MATERIALS AND METHODS.—The insecticides used in this study were p-p′ isomer of DDT, lindane, and technical grades of parathion and chlordane. They were all used as emulsions, having xylene as the solvent and 10 per cent Triton X 100[4] as emulsifier. Dilutions were made in water.

The equipment used for generating insecticidal mists has been illustrated and described by Ebeling (1953). The test insects anesthetized by carbon dioxide gas were exposed to the mist for 2 minutes, after which they were removed to glass jars and provided with food. Five mls. of the emulsion were used in every case. Mortality counts were taken 24 hours after treatment. The populations of *P. maidis* for insecticidal treatments were field-collected. Separation of the leafhoppers into categories according to sex and form, such as macropterous male, macropterous female, brachypterous male and brachypterous female, was made at the time of mortality counts. The test

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[3] Present address: Division of Entomology, Indian Agricultural Research Institute, New Delhi-12, India.

[4] Rohm & Haas Co., Philadelphia, Pa.

Table 1.—L.C.$_{50}$ values and their fiducial limits (p = 0.05) in mgs. of the insecticide per ml. of the emulsion, used against *Peregrinus maidis*.

Insecticide	Value[a]	Macropterous		Brachypterous		5th Instar Nymph
		Male	Female	Male	Female	
p−p′ isomer of DDT	1	0.192	0.207	0.081	0.176	0.232
	2	0.256	0.234	0.121	0.030	0.281
	3	0.124	0.184	0.054	0.016	0.191
Lindane	1	0.053	0.059	0.039	0.070	0.263
	2	0.060	0.064	0.046	0.078	0.289
	3	0.046	0.054	0.034	0.063	0.239
Parathion	1	0.019	0.028	0.014	0.026	0.030
	2	0.021	0.030	0.014	0.028	0.032
	3	0.018	0.025	0.013	0.024	0.029
Chlordane	1	1.537	1.770	0.480	1.132	1.143
	2	1.747	2.037	0.597	1.451	1.257
	3	1.353	1.539	0.386	0.884	1.038

[a] 1. L.C.$_{50}$. 2. Upper fiducial limit. 3. Lower fiducial limit.

populations of *C. mundulus* were collected in the field as nymphs and reared in the laboratory. The two categories of *C. mundulus* adults according to sex were treated separately. Toxicity of the insecticides to the fifth instar nymphs of both the species was also determined.

All statistical calculations for the L.C.50 values (concentrations to kill 50 per cent of the test population) were made according to Finney (1947).

Results and Discussion.—Tables 1 and 2 summarize toxicity results of the insecticides used against *P. maidus* and *C. mundulus*, respectively.

DDT.—There are no significant differences between the susceptibilities of the two sexes of either macropterous or brachypterous form. The female of the two forms of *P. maidis* are also equally susceptible. However, the brachypterous male is 2.4 times as susceptible as the macropterous male. The male of *C. mundulus* is 2.4 times as susceptible as the female and two times as susceptible as the nymph. Comparisons between the two species show that on the whole DDT is more toxic to *C. mundulus* than to *P. maidis*.

Lindane.—Although the two sexes of the macropterous form do not differ in their response, the brachypterous male is 1.7 times as susceptible as the brachypterous female. The nymph is the least susceptible category. The male of *C. mundulus* is 4.5 times as susceptible as the female and 7.8 times as susceptible as the fifth instar nymph. Lindane appears to be much more toxic to *C. mundulus* than to *P. maidis*. The male of *C. mundulus* is 29.4 times as susceptible as the macropterous male and 21.7 times as susceptible as the brachypterous male of *P. maidis*. The differences between the females of the two species are less marked. However, the fifth instar nymph of *C. mundulus* is 18.8 times as susceptible as that of *P. maidis*.

Parathion.—The females of both the forms of *P. maidis* appear to be less susceptible than their respective males. Although the females of the two forms are of the same order of susceptibility, the brachypterous male is 1.4 times as susceptible as the macropterous male. The male of *C. mundulus* is 2.8 times as susceptible as the female, which in turn is 1.4 times as susceptible as the nymph. Comparisons between the two species show no differences between the females and the nymphs. However, the male of *C. mundulus* is more susceptible than those of *P. maidis*.

Chlordane.—The two sexes of the macropterous form are equally susceptible. But the male of the brachypterous form is 2.4 times as susceptible as the female. Both sexes of the brachypterous form are more susceptible than those of the macropterous form. The male of *C. mundulus* is 7.1 times as susceptible as the female and 8.2 times as susceptible as the nymph. Comparisons of the two species show that here again *C. mundulus* is more susceptible than *P. maidis*.

Summary.—The insecticides in descending order of efficacy against *Peregrinus maidis* are: parathion, lindane, DDT and chlordane, and against *Cyrtophinus mundulus:* lindane, parathion, DDT, and chlordane.

The two sexes of the macropterous form of *P. maidis* differ significantly in their response only to parathion. On the other hand the male of the brachypterous form is more susceptible than the brachypterous female to practically every insecticide. The brachypterous male is more susceptible than the macropterous male of *P. mundulus*. The female of the two forms differ in their response only to chlordane.

The male of *C. mundulus* is more susceptible to every insecticide used than the female and the fifth instar nymph.

All the four insecticides are more toxic to the predator than to the pest species.

Table 2.—L.C.$_{50}$ values and their fiducial limits (p = 0.05) in mgs. of the insecticide per ml. of the emulsion used against *Cyrtophinus mundulus*.

Insecticide	Value[a]	Male	Female	5th Instar Nymph
p−p′ DDT	1	0.065	0.155	0.131
	2	0.074	0.172	0.143
	3	0.058	0.140	0.121
Lindane	1	0.0018	0.0081	0.014
	2	0.0022	0.0089	0.015
	3	0.0015	0.0073	0.013
Parathion	1	0.0074	0.021	0.030
	2	0.0080	0.025	0.031
	3	0.0068	0.015	0.028
Chlordane	1	0.058	0.411	0.475
	2	0.067	0.502	0.526
	3	0.050	0.337	0.430

[a] 1. L.C.$_{50}$. 2. Upper fiducial limit. 3. Lower fiducial limit.

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Soil Treatments for Brachyrhinus Control in Strawberries[1]

PAUL M. EIDE,[2] *Washington State College, Northwestern Washington Experiment Station, Mount Vernon*

The strawberry root weevil, *Brachyrhinus ovatus* (L.) and the black vine weevil, *Brachyrhinus sulcatus* (F.), are among the most important insect pest of strawberries in the northwest counties of Washington and cause extensive losses in spite of the applications of tons of bait each year for their control. The great success of some of the newer insecticides against other soil-inhabiting insects suggested a new approach to the weevil problem, namely, that of killing the grubs in the soil rather than the egg-laying adults, since the grubs are responsible for practically all of the damage in strawberries. The tests reported here were all conducted in more or less the same manner and are part of a series put on each year in the northwest counties of Washington, beginning in 1950.

PROCEDURE.—Each experiment consisted of a portion of a commercial field with a history of weevil damage. Plots were 50- or 75-foot portions of a single row, arranged in randomized block design with four replications. The various test materials were applied with a small lawn fertilizer spreader in bands or strips 18 inches wide and were worked into the soil with a rotary tiller to a depth of 3 or 4 inches. The strawberry plants were then set out in the center of these treated strips.

Only one of three experiments started in 1950 developed a natural infestation. This, located at Silvana, Washington, became infested with *B. sulcatus* in sufficient numbers to destroy most of the mother plants in the check plots. The results (Eide 1952) indicated that aldrin and dieldrin gave excellent control at 5 and 10 lbs. per acre, chlordane good control at 10 and 20 lbs., while BHC and lindane were not effective even at 4 lbs. of gamma isomer per acre. This field was later plowed by the owner so that further observations could not be made. In the various other test plots, no natural infestation developed during 1951, 1952, or 1953. In 1953, artificial infestation was attempted. Adults of *B. ovatus* were collected in a field of alta fescue on Whidbey Island. A thousand or so were picked up with an aspirator from the ground beneath piles of hay. The owner then threshed his crop, bringing the seed to a local company for cleaning. A couple of sacks of screenings from this seed crop yielded several thousand weevils.

Adults of *B. sulcatus* were collected from abandoned strawberry fields by sweeping with an insect net at night. The weevils were placed in ice cream cartons and fed daily on fresh strawberry leaves. About 150 *B. sulcatus* or 300 *B. ovatus* in a quart-sized carton seemed to be about the optimum number. Plain ice cream cartons rather than the waxed type used for frozen foods were preferred, since the eggs and frass that collected in the bottom tended to mold in the air tight, waxed type. The black vine weevils were more adaptable to this type of treatment, yielding far more eggs in proportion to the number of weevils.

Adults of *B. ovatus* started laying eggs immediately after being placed in the cups (July 27). These eggs started hatching in about 10 days. *B. sulcatus* were first placed in the cups July 21, but laid no eggs until July 29. This same observation regarding *B. sulcatus* has been made for 3 consecutive years. *B. sulcatus* apparently do not begin to lay eggs until the latter part of July, after strawberry harvest, although they begin to emerge from the soil at a much earlier date (June 24, 1954). This applies only to the current year's brood, however. Adults wintering over from the previous year started to lay eggs as soon as they were put in a warm place. The smaller species emerged from the soil at the same time but started ovipositing much earlier.

The eggs were collected from the cartons every 2 weeks, at which time a few had usually hatched. The weevils, dried leaves, and trash were separated with a screen and the remaining mixture of frass and eggs weighed. The total weight was divided by the number of plots to be infested, and the individual samples weighed out in small plastic vials on a balance accurate to 0.01 gram. Usually there were not enough eggs at any one time to infest all plots of an experiment, in which case two or more replications were treated. From 0.5 to 0.7 gram was used, which was estimated to contain from 800 to 1000 eggs. The number might vary between replications, but each material in each replication received nearly the same number of eggs at about the same time.

The eggs were distributed in a 5-foot section of each single-row plot, 10 feet from the end of the plots for the *B. ovatus* eggs and 20 for those of *B. sulcatus*. The site was marked by stakes so that strings could be stretched across the rows for convenience in "seeding" the eggs and sifting the soil for grubs later. Eggs were shaken around the crowns of the plants since the weevils oviposit indiscriminately in the soil beneath the strawberry plants.

The dates of egg deposition were as follows:

Rickdall plots, Burlington, Washington
- Blocks A—August 18, 1953: B, C & D—August 19, 1953—*B. ovatus* eggs
- Blocks A & B only—September 3, 1953—*B. sulcatus* eggs

Pictsweet plots, Monroe, Washington
- Blocks A, B, C, & D—August 11, 1953—*B. ovatus* eggs
- Blocks C & D—August 14, 1953—*B. sulcatus* eggs
- Blocks A & B—September 2, 1953—*B. sulcatus* eggs

RESULTS.—The effectiveness of the different treatments was evaluated in April and May, 1954, by sifting 2 square feet of soil 5 inches deep from each egg-infested area and counting the weevil larvae. The results are given in tables 1 and 2. The counts were somewhat inconsistent but show certain trends, at least. The number of grubs maturing was surprisingly small, considering the number of eggs used. The highest count was 40 grubs in 2 square feet. Only one plant in all the infested areas examined was noticeably injured. This was in a plot (DDT 5 pounds) that had only 20 grubs in 2 square feet.

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Table 1.—Effect of insecticides against *Brachyrhinus* near Burlington, Washington.[a]

Materials (Dilute Dusts)	Pounds Active Ingredient per Acre	(*B. ovatus*) Replications					(*B. sulcatus*) Replications		
		A	B	C	D	Total	A	B	Total
Chlordane	5	4	2	4	7	17	8	29	37
Chlordane	10	2	0	17	0	19	15	24	39
Chlordane	15	1	0	1	0	2	2	11	13
Aldrin	2.5	6	1	13	1	21	3	1	4
Aldrin	5.0	0	0	0	3	3	14	2	16
Aldrin	7.5	0	0	0	0	0	0	1	1
Dieldrin	2.5	0	4	3	0	7	3	7	10
Dieldrin	5.0	0	0	0	0	0	2	3	5
Dieldrin	7.5	0	2	0	0	2	1	3	4
BHC	1.0[b]	18	12	27	4	61	11	24	35
BHC	2.0[b]	1	2	29	7	39	12	2	14
Toxaphene	5.0	7	12	9	37	65	22	9	31
Toxaphene	10.0	5	31	25	20	81	15	29	44
DDT	10.0	5	24	25	11	65	8	12	20
DDT	15.0	15	4	12	5	36	12	1	13
Methoxychlor	10.0	14	9	38	15	76	40	12	52
Methoxychlor	15.0	24	12	19	5	60	21	21	42
Untreated		25	15	17	17	74	11	12	23
Untreated		10	5	26	13	54	13	22	35

[a] Treatments applied to the soil in April, 1950. Counts made in April, 1954. Each figure represents total grubs in 2 square feet of treated row.
[b] Gamma isomer.

It was unfortunate that only two replications of the plots at Burlington could be infested with eggs of *B. sulcatus*. For some reason all of the weevils of both species died suddenly before sufficient eggs had been laid to infest the last two replications. The strawberry leaves used to feed them probably became contaminated in some way.

Areas infested with *B. ovatus* in the experiment at Monroe were not examined, except for the untreated checks and some of the least likely treatments which showed scarcely any infestation. Practically the only grubs of this species found in the whole experiment were in a few small spots at the extreme edge of the field, where a slight natural infestation occurred. It is interesting to note that although the number of grubs here was not great (15 to 20 per square foot), the damage was quite severe.

One other treatment was used in the test at Monroe which is not included in the table. This was a proprietary mixture of coal tar oils, with a small amount of BHC, applied at the rate of about 5 gallons per acre in 200 gallons of water. Because of the accidental loss of two vials of eggs, these plots in Blocks A & B were not infested. In Blocks C & D this treatment had 7 and 17 grubs per square foot, respectively.

Table 2.—Effect of insecticides against *Brachyrhinus sulcatus* in Pictsweet's berry field, Monroe, Washington. April 5, 1954.[a]

Materials		Pounds Active Ingredient per Acre	Replications				Totals
			A	B	C	D	
Aldrin	2.5% dust	3.5	0	0	0	0	0
Aldrin	2.5% dust	5.0	0	0	0	0	0
Chlordane	5.0% dust	7.0	0	0	0	0	0
Chlordane	5.0% dust	10.0	0	1	0	6	7
Dieldrin	2.5% dust	3.5	0	0	0	2	2
Dieldrin	2.5% dust	5.0	0	0	0	0	0
Heptachlor	2.5% dust	3.5	0	0	0	0	0
Heptachlor	2.5% dust	5.0	0	0	0	0	0
DDT	5.0% dust	10.0	13	20	1	0	34
DDT	5.0% dust	20.0	19	11	0	0	30
Aldrin	2 lbs./gal-liq.	5.0	0	0	0	0	0
Chlordane	4 lbs./gal-liq.	10.0	6	4	14	1	25
BHC	1% g.i.	5.0	9	39	15	2	65
BHC	1% g.i.	7.0	0	10	4	0	14
Untreated			6	34	7	0	47

[a] Treatments applied to the soil April 28, 1952. Each figure represents number of larvae sifted from 2 square feet of soil.

Although the counts between different plots with the same treatment varied greatly at times, four materials appeared effective. Of these, aldrin, dieldrin, and heptachlor were superior to chlordane. Aldrin and dieldrin gave control of *B. ovatus* at 5 and 7.5 pounds per acre for 4 years, but only the 7.5-pound dosage seemed effective for *B. sulcatus* for this long a period.

DDT, methoxychlor, toxaphene and BHC gave no apparent control, as in the previous test. In the 1952 treatments, heptachlor was apparently as effective as aldrin or dieldrin, all of which showed excellent results at both 3.5 and 5 pounds per acre. The reason for the variation between different plots of the same treatment cannot be explained at present.

Flavor evaluation tests were conducted by the Food Technology Department at Oregon State College using samples of berries from the plots treated with aldrin, dieldrin, heptachlor, chlordane, and BHC in the experiment at Monroe. With panels of a hundred or more college students for each material, no off-flavor could be detected in any of the samples. The samples were picked in July, 1953, the first harvest year for the field.

Aldrin has been used quite extensively for weevil control in strawberries in the northwest counties of Washington during the past 2 years, and chlordane even longer. So far, no infestations in treated fields have been reported.

Only one infestation in a treated field has been found. This was in the field adjoining the plots at Monroe, which had been treated with chlordane in liquid form prior to planting in 1952. However, this turned out to be an entirely different species, known as the raspberry bud weevil, *Nemocestes incomptus* (Horn). This weevil has been reported as feeding on raspberry buds in the spring, but no record could be found of its being a pest in strawberries. The grubs found were very small, and there is a possibility of their being destroyed by contact with the treated soil over a considerable period of time. There is also a possibility of the bud weevil being inherently more resistant to the treatments, just as *B. sulcatus* seems to be slightly more resistant than *B. ovatus*.

SUMMARY.—Plots treated with various insecticides prior to planting strawberries in 1950 and 1952 were infested with eggs of two species of *Brachyrhinus* in the fall of 1953. The effectiveness of the different materials was compared by larvae counts made in the infested areas in 1954. Aldrin and dieldrin at 5 and 7.5 pounds and chlordane at 15 pounds per acre gave excellent control of *B. ovatus* for the longer period of time. *B. sulcatus* was apparently a little more difficult to control, requiring 7.5 pounds per acre of either aldrin or dieldrin. Aldrin, dieldrin, and heptachlor gave effective control of *B. sulcatus* the second year at 3.5 and 5 pounds per acre. Toxaphene, DDT, BHC, and methoxychlor did not give control at any of the dosages tried.

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Reduction of Malathion Residues on Vegetables by Washing[1]

FLOYD F. SMITH, PAUL GIANG and EDGAR A. TAYLOR, *Entomology Research Branch, Agric. Res. Serv., U.S.D.A.*

On greenhouse lettuce treated with aerosols containing malathion, a residue of 21 p.p.m. found 1 hour after application declined to approximately 0.3 p.p.m. in 9 days (Smith & Giang 1954). On green onions in a garden malathion residues from a dust and emulsion and wettable-powder sprays were found to be 4, 11, and 19 p.p.m., respectively, after 1 hour. In the absence of rain the residues declined rapidly after the first day, but 0.4 to 0.8 p.p.m. was present until the sixth day. No residues were found following a heavy rain on the second day after similar applications in nearby plots. This apparent removal by rain suggested the possibility of removing or reducing residues by the ordinary washing of vegetables as done by the housewife in preparing them for the table. Experiments were therefore conducted at Beltsville, Md., whereby several common vegetables were treated with malathion and samples were washed in accordance with procedures suggested by Miss Gladys Gilpin of the Human Nutrition Research Branch.

For these washing experiments one sample of vegetables from each treatment was dropped into a small sink partly filled with tap water, vigorously lifted in and out of the water for 30 seconds, and then drained on clean paper. Another sample was washed as the first one and then given a similar second washing for 30 seconds in another batch of clear water. When free water had drained away after the washing, the samples were ready for analysis.

Vegetables were grown in field plots at Beltsville especially for these experiments and were treated with malathion when ready for harvest from August to October 1954. A 4% malathion dust was applied at the rate of 44 pounds per acre. Sprays containing a 25% malathion wettable-powder or a 50% emulsifiable concentrate were applied at the rate of 100 gallons per acre. For all treatments the application rate of malathion was 1.75 pounds per acre, which is slightly higher than is ordinarily used.

After the sprays had dried, samples of the crop given each treatment were harvested and divided into three equal lots; one was analyzed unwashed and the other two were given one or two washes as described above. Most of the samples were harvested about 1 hour after the treatment, were washed during the second hour, and then, almost immediately, extracted for chemical analyses. They were extracted with redistilled carbon tetrachloride without either cutting up or further washing, and the analyses were made by the colorimetric method developed by the American Cyanamid Company (Norris *et al.* 1954). The results of all analyses were corrected for the determination on samples of untreated material. Although none of the untreated check vegetables contained malathion, some gave slight reactions characteristic for the plants. The difference in intensity of color between extracts from check and treated samples was calculated as malathion.

Table 1 shows that the leafy vegetables—beet tops, broccoli, kale, and lettuce—had a higher malathion residue than did snap beans, beet roots, okra pods, or tomato fruits. Generally the residues on unwashed vegetables were lowest from dusts and highest from wettable-powder sprays. Washing usually reduced residues of the dusts to lower levels than those of the sprays. One 30-second washing reduced all the residues on snap beans, okra, and tomato below 1 p.p.m. Residues from dust on beet (tops and roots), broccoli, and kale were also reduced by one washing. On lettuce residues from dust were not reduced below 1 p.p.m. when washed for 30 seconds 1 hour after treatment but they were reduced when washed after 24 hours.

Table 1.—Residues on vegetables sprayed or dusted with malathion as affected by washing.

Vegetable	Hours Between Application and Harvest	Formulation	Residue (p.p.m.)		
			Unwashed	Washed 30 Seconds	Washed 60 Seconds
Beets: Tops	1	Dust	6.52	0.31	0.24
		Emulsifiable concentrate	5.78	1.33	.24
		Wettable powder	11.49	1.09	.25
Roots	1	Dust	.42	.18	0
Broccoli	1	Dust	9.30	.70	.55
		Emulsifiable concentrate	14.05	2.40	2.30
		Wettable powder	15.00	3.60	1.70
Kale	1	Dust	16.40	.20	.20
		Emulsifiable concentrate	11.91	.94	.34
		Wettable powder	19.71	4.20	.69
Lettuce	1	Dust	14.69	1.17	.67
		Emulsifiable concentrate	16.51	2.55	.61
		Wettable powder	17.70	1.77	1.24
	24	Dust	2.60	.48	.38
		Emulsifiable concentrate	4.59	1.24	.36
		Wettable powder	3.64	1.03	.58
Okra pods	1	Dust	3.31	.28	.18
		Emulsifiable concentrate	3.40	.48	.20
		Wettable powder	7.71	1.40	.51
Snap beans	1	Dust	3.23	0.34	0.15
		Emulsifiable concentrate	6.98	.60	.53
		Wettable powder	8.63	.53	.48
	14	Dust	.15	0	0
		Emulsifiable concentrate	.83	.19	0
		Wettable powder	1.88	Tr	Tr
Tomato fruits	1	Dust	1.83	.11	.18
		Emulsifiable concentrate	1.30	.10	.13
		Wettable powder	3.50	.20	.28

Washing for 60 seconds reduced the residues below 1 p.p.m. on all treated vegetables except lettuce treated with the wettable-powder spray and broccoli receiving either spray.

Incidental to these experiments analyses of samples of broccoli were made in a commercial freezing plant at Exmore, Va., in cooperation with L. P. Ditman, University of Maryland. Broccoli from fields that had been sprayed with an emulsion to give 1.25 pounds of malathion per acre contained residues ranging from 10.4 to 13.2 and averaging 12.4 p.p.m. in four samples harvested one hour after treatment. The regular washing and blanching processes by steam in preparing the broccoli for freezing reduced these residues to 0.30 and 0.66 p.p.m. in two samples. Broccoli washed and blanched by hot water in an alternate process contained 0.30 and 0.48 p.p.m.,

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respectively, in two other samples. As in the Beltsville tests, samples were extracted for analysis almost immediately after blanching. Unwashed samples of the broccoli exposed to 0.3 inches of rain and harvested 24 and 48 hours after treatment contained 1.26 p.p.m., and 0.48 p.p.m., respectively, of malathion.

From these experiments it appears that malathion residues can be reduced to low levels if the vegetables are washed by the usual procedures in their preparation for the table or for processing.

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A New Bioassay Method for Evaluation of Insecticide Residues[1]

H. P. BURCHFIELD and ALBERT HARTZELL, *Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York*

Satisfactory chemical methods have been developed for the determination of DDT (Schechter *et al.* 1945), chlordane (Davidow 1950), parathion (Averell & Norris 1948), and other economically important insecticides, but bioassay methods continue to attract attention because of their high sensitivity and the broad range of compounds to which they can be applied. This last factor is particularly important for the detection of insecticide residues in food crops since the nature of the contaminant is frequently unknown and it may be difficult to select the appropriate chemical procedure. A preliminary bioassay will indicate the presence or absence of a wide variety of compounds in advance of chemical analysis, and in many cases may be the only test required when the response is low.

Hoskins & Messenger (1950) and Hoskins *et al.* (1952) have used the common house fly to detect the presence of insecticides in extracts from food crops through contact action. Frawley *et al.* (1952) have described a modified procedure in which the extracts are administered orally to eliminate the reduction in contact toxicity caused by the presence of plant lipids. Nolan & Wilcoxon (1950) described a method for the bioassay of parathion using larvae of *Aedes aegypti* (L.), and Hartzell (1950) and Hartzell & Storrs (1950) applied the procedure to 16 different insecticides in the presence of extracts from food crops. Bushland (1951) has also used mosquito larvae for the detection of organic insecticides in animal products.

All of these procedures are based on the same fundamental technique. The solution containing the insecticide is diluted serially and a fixed number of test organisms are exposed to a preparation made from each dilution. After a standard incubation period (usually 24 to 48 hours) the percentage mortality is estimated by visual observation and the amount of insecticide determined from a reference curve relating mortality in probit units (Finney 1947) to the logarithm of the concentration. The data for the reference curves are obtained by exposing test organisms withdrawn from the same batch to a series of known concentrations of the pure compound.

This method has had wide acceptance in toxicological work and no doubt will continue to be used for most applications. Nevertheless it has some serious disadvantages when applied to the routine bioassay of insecticides.

When mosquito larvae are used as the test organisms it is frequently difficult to decide whether an individual should be classified as living or dead based on visual inspection alone. In regions of intermediate kill many moribund larvae are found which have obviously been affected by the toxicant but which are still capable of movement. The presence of these moribund larvae increases the difficulty of counting and so limits the number of individuals which can be used in a single test. This in turn further reduces accuracy since the error in sampling the parent population is large when a small number of larvae are used in each test. In addition, the 24- to 48-hour holding period usually required is long compared to the time required for most chemical analyses and a shorter test would be desirable from the standpoint of process control.

Recently, a new procedure has been proposed based on the response of mosquito larvae to light (Anon. 1952, Burchfield *et al.* 1952). It has long been known that mosquito larvae (Bates 1949, p. 145) and other lower forms of life (Detmer & Moor 1898, p. 423; Mast 1911) move rapidly away from an intense light source and congregate where the net illumination is least. This response is reduced by the presence of toxic materials, so it can be used as the basis for an automatic segregation of individuals by setting up an arbitrary time and distance for migration. Larvae which migrate beyond a fixed point in a period of 1 minute are regarded as unaffected; those which fail to do so are regarded as moribund. This provides for a classification which is independent of the judgment of the operator, since it is based entirely on an arbitrary physiological response. The ability of larvae to move away from a light source is reduced by the presence of insecticides long before death occurs; thus it is possible to get results in a much shorter time than required for mortality estimations. The rapidity with which this response occurs makes it possible to dispense with dilution

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series almost entirely and obtain definitive results at a single concentration of the crop extract. The time required for inhibiting 50 per cent of the larvae is used as the criterion of response and this is proportional to the concentration of insecticide. The time for 50 per cent response may vary from 1 minute to 5 hours depending upon the type and concentration of insecticide. Most insecticides used in agriculture inhibit in 1 hour or less at concentrations of 0.1 to 1.0 p.p.m. so the method has both the speed and sensitivity required for bioassay.

THE PHOTOMIGRATION TEST.—The chamber used for photomigration is a semicircular glass trough 10 inches in length supported by a wooden cradle (Fig. 1). The chamber is partitioned off at 1 inch and 3 inches from the end by movable porous barriers mounted on brass uprights. Illumination parallel to the longitudinal axis of the trough is furnished by a 500-watt General Electric projection lamp housed in a flexboard box with a window facing the near end of the chamber. At the beginning of an experiment the light is turned off and the barrier nearest the end of the chamber lowered. One ml. of a solution of the insecticide or plant extract in acetone or carbitol is added to 99 ml. of water containing 100 mosquito larvae and the time of addition recorded. The suspension is then added to the chamber and the larvae are confined behind the 1-inch barrier. When incipient inactivation becomes apparent the barrier is raised and the light turned on. After exactly 1 minute the barrier at the 3-inch mark is dropped, and the larvae trapped behind it are counted and classified as inactivated. Untreated larvae invariably migrate to the far end of the trough in 1 minute. The time is recorded and the experiment repeated at intervals until 70 to 90 per cent of the larvae have become inactivated. Time is then plotted against percentage inhibition in probit units and the time required for inhibition of 50 per cent of the population (T50) is estimated by interpolation.

The T50 is proportional to the concentration of insecticide, hence the amount of toxic material in an unknown sample can be estimated by comparison with T50 values obtained at known concentrations of the same substance. This relationship is not linear, but it is usually satisfactory to interpolate results from a graph of the logarithm of the T50 against the reciprocal of the concentration in parts per million (Fig. 2).

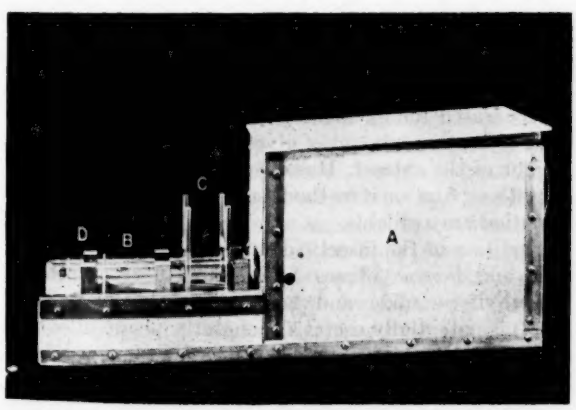

FIG. 1.—Apparatus for measuring response of mosquito larvae to light. (A) Lamp housing. (B) Migration chamber. (C) Barrier posts. (D) Chamber support. (Photo by William G. Smith, Jr.)

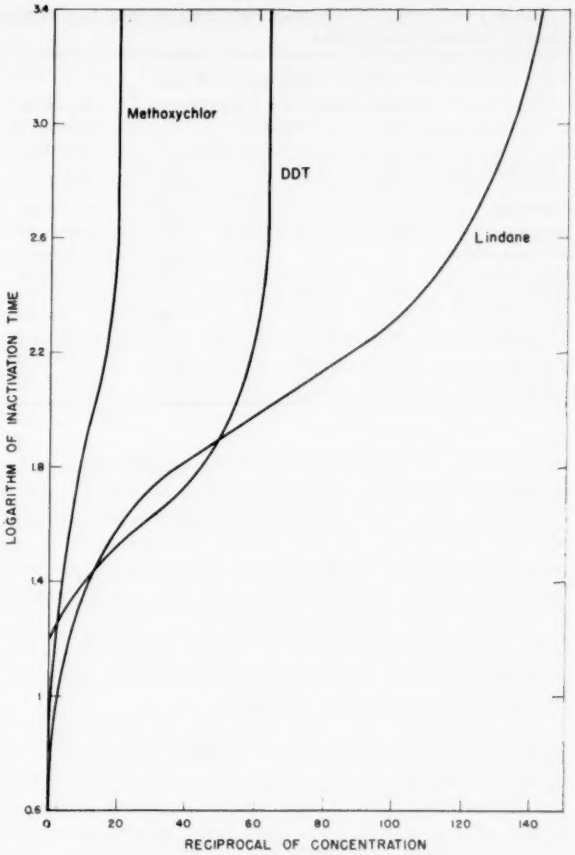

FIG. 2.—Relationship of logarithm of time required for inactivation of 50 per cent of a larval population toward light and reciprocal of concentration. (Graphs by William G. Smith, Jr.)

Kinetic studies (Burchfield & Storrs 1954) have shown that T50 is more accurately related to concentration (c) by the equation

$$T50 = \sqrt{\tau^2 + \frac{A}{(c - c_o)^n}}$$

where τ is the minimum time required to produce 50 per cent inactivation by a given insecticide at infinite concentration, c_o is the minimum amount of material that will produce 50 per cent inactivation in an indefinitely long time, and n and A are empirical constants. This equation is useful in comparative studies on rates of inactivation by various materials (Burchfield & Storrs 1954) but the evaluation of the constants is too tedious to make it worthwhile in bioassay. Usually it suffices to plot log T50 against $1/c$ and interpolate from the curve.

In order to obtain reproducible results it is necessary to use larvae reared under carefully standardized conditions in all tests (Burchfield *et al.* 1953, Granett & Haynes 1944). Second instar larvae at an age of 20 to 22 hours are generally employed but other types may be

Table 1.—Typical T50 values obtained at four concentrations of various insecticides.

Insecticide	T50 in Minutes at Concentration of Insecticide (p.p.m.)				Optimum Bioassay Range (p.p.m.)
	10	1	0.1	0.01	
Allethrin	<1	<2	43	>300	1.0–0.1
Lindane	<3	7.5	25.4	182	0.2–0.01
Methoxychlor	4	4	31.4	>300	0.2–0.08
Parathion	7.8	19.0	50	>300	0.2–0.02
DDT	8.3	11.6	18.4	116	0.1–0.005
Heptachlor	15.5	16.0	29.5	93.5	0.1–0.005
Chlordane	16.7	22.1	47.2	170	0.2–0.01
Aldrin	26.6	31.3	45.4	148	0.2–0.005
Toxaphene	36.5	46.2	144	>300	1.0–0.05

satisfactory. Temperature control, cleanliness, and a satisfactory nutrient balance are all required to obtain uniformity. Standard calibration curves can be used when approximate results are satisfactory, but for more precise measurements the curves must be redetermined for each batch of larvae. Reproducibility of T50 results against a standard material (heptachlor at 0.1 p.p.m.) varies from $1\frac{1}{2}$ to $2\frac{1}{2}$ minutes at a 30-minute testing level. It is possible that this can be improved upon by further refinements in the rearing methods.

Inactivation by Different Insecticides.—A survey of the more important organic insecticides used in agriculture has shown that all of them will inhibit the photomigration of 50 per cent of the larvae in an hour or less at concentrations of 1.0 p.p.m., and most of them at 0.1 p.p.m. (Table 1). Many are still highly effective at 0.01 p.p.m., and on a few, T50 values can be obtained at 0.002 p.p.m. in less than 5 hours. This high sensitivity and the broad range of activity measurable at a single concentration is advantageous when the nature and amount of the residue are unknown. At concentrations greater than 1 to 10 p.p.m. the estimations become inaccurate since the T50 tends to reach a limiting value and the change in time with respect to concentration in this region is small. Below 1.0 to 0.1 p.p.m. the curves break rapidly and comparatively small changes in concentration lead to large changes in T50. Below 0.01 p.p.m. inactivation times become inconveniently long and the reproducibility of the measurements is comparatively poor. Yet between these limits there is a wide range where most of the materials in general use can be determined with reasonable accuracy.

The rapidity with which a material acts at high concentrations is not related to its persistence on dilution. Thus allethrin is the fastest material at 1.0 p.p.m., one of the slower at 0.1 p.p.m., and fails completely at 0.01 p.p.m. Aldrin is one of the slower at 1.0 p.p.m. but is still highly effective at 0.01 p.p.m. On the other hand, lindane acts rapidly at high concentrations and persists well on dilution. Because of this, the optimum ranges for bioassay differ considerably, but for all of the insecticides considered in this group the practical upper limit is less than 1 p.p.m.

Mixtures of insecticides represent a special case which cannot be evaluated without some knowledge of the components (Storrs & Burchfield 1954). Mixtures of structural analogues such as DDT and methoxychlor give T50 values which are less than the arithmetic averages of the components. This apparently indicates similar joint action. On the other hand mixtures of structurally unrelated compounds such as methoxychlor and chlordane give T50 values which are sometimes higher than those of either pure component when the total concentration of insecticide is kept constant. This may be caused by independent joint action. These observations may be of some interest in establishing similarities and differences in insecticidal action but are relatively unimportant from the standpoint of bioassay. In all cases so far observed the occurrence of mixtures would not result in a serious masking of toxicity.

Not all physiologically active materials are effective in the T50 test. Among these are many water-soluble materials, such as nicotine and sodium arsenate, which will not inactivate at 10 p.p.m. in less than 5 hours. Sodium cyanide is effective in 40 to 50 minutes at 10 p.p.m. but is inactive at 1.0 p.p.m. However, aside from some of the acaricides, rotenone is the only important liposoluble insecticide so far tested which failed to inactivate larvae in the T50 test. The evidence to date indicates that the test is more or less specific for liposoluble compounds which act as neural or muscular poisons.

Interferences.—The fact that many general metabolic poisons do not produce a rapid response in the photomigration test greatly reduces the possibility that observed toxicity may be due to naturally occurring plant products with some obvious exceptions such as the pyrethrins. Organic acids and alkaloids do not produce an effect except at very high concentrations and these can be removed by comparatively simple extractions.

However, as in most bioassay methods the presence of lipids tends to mask toxicity through preferential solubilization of the insecticide in the oil globules (Hartzell *et al.* 1954). Thus in the presence of 100 p.p.m. olive oil the T50 value obtained on a solution containing 0.1 p.p.m. heptachlor is increased from *ca.* 30 minutes to *ca.* 100 minutes. This represents a loss corresponding to 90 per cent of the original activity. The plant pigments such as the chlorophylls, carotenoids, and xanthophylls can be effectively removed by chromatographic adsorption on calcium carbonate (Burchfield *et al.* 1952) or Florosil (Hartzell *et al.* 1954), but the nonadsorbable glycerides and waxes which remain still constitute a serious interference. Where sensitivity can be sacrificed this can be compensated for by making up the reference standards with a constant amount of glyceride corresponding to the weight of the extract. However, it is usually best to attempt a separation if methods suitable to meet the specific situation are available.

Partition of the insecticide and lipid between acetonitrile and hexane (Jones & Riddick 1952) or between dimethylformamide and hexane (Burchfield & Storrs 1953) is potentially useful although the possibilities have not been fully investigated. For the photomigration method, steam distillation is particularly attractive when the insecticide is volatile enough (Hartzell *et al.* 1954). The steam distillate can be collected and used in the test directly without further extraction or concentration. Lindane and heptachlor can be recovered almost quantitatively from olive oil by this method, but the recoveries

of DDT and methoxychlor are less satisfactory. A general method has not yet been developed that can be applied to all situations.

APPLICATIONS.—The photomigration method has been used for the estimation of DDT, methoxychlor, lindane, parathion, aldrin, heptachlor, and chlordane in extracts from raw and processed food crops. The most extensive investigations were made on potatoes, yams, cabbage, turnips, onions, corn, and carrots which had been treated with chlordane or heptachlor at recommended rates for the control of insect infestation during the 1952 growing season (Hartzell *et al.* 1954). After harvesting, the samples were extracted and analyzed colorimetrically[2] (Davidow 1950, Polen & Silverman 1952).

The extractions were made with *n*-pentane and plant pigments removed by chromatographic adsorption on Florosil. In the case of the samples containing chlordane, residual lipids were removed by an additional purification step. Concentrates from the Florosil columns were passed through activated alumina which absorbed the chlordane and permitted the lipids to pass through with the percolates. The columns were then eluted with ethyl ether and the eluates evaporated to dryness and made up to standard volume with acetone for chemical analysis and bioassay.

The average chlordane content obtained on 64 samples representing the seven different crops was 0.035 p.p.m. by chemical analysis compared to 0.033 p.p.m. by bioassay. The best agreement was obtained on carrots where the ratio of chemical analysis to bioassay was 1.0 and the poorest on yams where the ratio was 1.9. Correlation coefficients varied from -0.185 to $+0.695$ with a weighted average of $+0.175$.

On the samples containing heptachlor where residual lipids were not removed, agreement of the average results obtained on each crop was not as good. The best results were obtained on extracts of onions where the ratio of chemical analysis to bioassay was 1.3 and the poorest on yams where the ratio was 8.7. The average heptachlor content of 80 samples based on the fresh weight of the crop was 0.017 p.p.m. by chemical analysis and 0.007 p.p.m. by bioassay. Correlation coefficients for each crop varied from $+0.906$ to -0.053 with an average weighted value of $+0.252$.

Average results obtained by the chemical and bioassay methods agreed very well for the determination of chlordane considering the small amount of residues present. With the samples containing heptachlor agreement was less satisfactory, probably because of the presence of residual lipids which masked the action of the insecticide in the bioassay test. Over-all correlation was significant at the 5 per cent level with an average coefficient of $+0.219$ and 115 degrees of freedom. Thus there was some relation between pairs of results but it was outweighed by other factors not subject to experimental control. This was not unexpected considering the nature of the samples and the limitation of the analytical procedures. The highest average residue content was 0.047 p.p.m. found on potatoes and the lowest was 0.003 p.p.m. found on yams. Ninety-two per cent of the samples contained less than 0.05 p.p.m. residual insecticide.

These values are close to the limits of sensitivity of both methods even when large samples are used. Duplicate determinations made by the colorimetric methods are reported to vary by as much as 100 per cent in this range while bioassay results may vary by 20 per cent. In view of this a high degree of correlation cannot be expected particularly when the differences between samples are small. The standard deviations of the means for the various crops were from 10 to 85 per cent of the average values; hence differences between samples from the same crop were frequently smaller than the errors inherent in the methods of assay.

The colorimetric methods tend to give high readings since impurities present in the extracts cause background absorption. On the other hand, bioassay results are generally low since lipids reduce the rate of insecticidal action. The true values are probably somewhere intermediate between the two extremes. On the samples containing chlordane this difference has been largely eliminated, and subsequent work on solvent partition and steam distillation indicates that it should be possible to work out suitable purification methods for other specific cases.

DISCUSSION.—The photomigration method provides a useful supplement to established methods of chemical analysis particularly when the nature and amount of insecticidal residue are unknown. A T50 value of 60 minutes or less obtained on an adequately prepared sample should indicate the absence of many insecticides in amounts greater than 0.1 p.p.m., and of most insecticides in amounts greater than 1.0 p.p.m. When required, more definitive data can be obtained by using larger sample sizes or longer reaction periods. Some insecticides such as lindane, heptachlor, and aldrin can be estimated at concentrations as low as 0.002 p.p.m. and this range can be extended by the use of larger samples.

The T50 test has several advantages over conventional methods of bioassay. Large numbers of test organisms can be used conveniently and the larvae are classified by an arbitrary physiological response which is independent of any personal judgment on the part of a laboratory technician. It is probable that the procedure could be made almost entirely automatic through the introduction of electronic mechanisms for the control of lights and barriers and for the counting of larvae. Equipment is currently under development which will transfar larvae from one compartment to another by means of a circulation pump.

The speed with which inactivation towards photomigration takes place is convenient since results can often be obtained in a few hours compared to the 24 to 48 hours required for most serial dilution methods. Thus results can be obtained more rapidly and adjustments readily made to meet unexpected situations. The range of activity for most insecticides is wide enough to permit preliminary estimations to be made at a single dilution. Thus lindane can be measured with reasonable accuracy at concentrations of 0.1 to 0.002 p.p.m. At higher concentrations accuracy is reduced but this can be compensated for by a single additional determination. When the nature of the insecticide is known, very small residues can be determined by the addition of a measured amount of the pure

[2] Extraction of samples and chemical analyses were carried out in the laboratories of the Velsicol Corporation, Chicago, Ill.

material since additive effects are very pronounced at low concentrations.

Mosquito larvae are convenient organisms to use in bioassay work since they can be reared on a 20- to 22-hour schedule and require a minimum of laboratory facilities. Eggs will survive for a month or more in a semi-desiccated condition, and if a central source of supply were available it would be unnecessary to maintain adult colonies in individual laboratories, This would be particularly important in food processing plants where the danger of contamination from insect fragments from escaped adults might be objectionable.

As with other chemical and bioassay methods the greatest problem is in the preparation of test samples free from plant contaminants. Interference from toxic materials is not likely to be important, but lipids definitely mask test results and must be removed. Satisfactory methods for doing this in specific cases have been worked out, but a general procedure applicable to all insecticide-crop combinations has yet to be developed.

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SCIENTIFIC NOTES

Acaricidal Properties of 2-Cyclohexyl-4, 6-Dinitrophenyl and Pentachlorophenyl Acetates[1]

A. P. YERINGTON and S. I. GERTLER,
Entomology Research Branch,
Agr. Res. Serv., U.S.D.A.

Preliminary laboratory tests indicated that some esters of acetic acid had considerable toxicity to mites (Bottger *et al.* 1953). Pentachlorophenyl acetate and 2-cyclohexyl-4,6-dinitrophenyl acetate, which proved to be the most toxic, were selected for further testing. Aramite and parathion were included for comparison. All compounds were tested in acetone sprays applied with a Potter spray tower.

Two species of mites were used, the citrus red mite, *Metatetranychus citri* (McG.), and the two-spotted spider mite, *Tetranychus bimaculatus* (Harvey). Both species were collected as needed, the citrus mites from orange trees and the two-spotted mites from castor bean plants.

TWO-SPOTTED SPIDER MITES.—Tests with eggs of the two-spotted spider mite were made by cutting away all but a small portion of a castor bean leaf, removing all motile stages, and spraying the eggs in situ. Mortality counts for eggs were made after four days and for adult mites after two days. The results are summarized in table 1. From comparisons of LC-50's it is seen that parathion was the most effective against the adults. It took 2.2 times as much 2-cyclohexyl-4,6-dinitrophenyl acetate, 8.9 times as much Aramite, and 18 times as much pentachlorophenyl acetate to achieve similar kills. Against the eggs 2-cyclohexyl-4,6-dinitrophenyl acetate was the most effective, 2.5 times as much parathion, 10.4 times as much Aramite, and 11.3 times as much pentachlorophenyl acetate being required to reach the 50 per cent mortality level.

Table 1.—Toxicity of some acaricides to the two-spotted spider mite (4 replicates).

Acaricide	Tests with Adults			Tests with Eggs		
	Concentration	Mortality in 2 Days	LC-50	Concentration	Mortality in 4 Days	LC-50
	Mg. per liter	*Per cent*	*Mg. per liter*	*Mg. per liter*	*Per cent*	*Mg. per liter*
Pentachlorophenyl acetate	1000	92		5000	93	
	500	82		2500	76	
	250	48	225	1250	53	1200
	125	28		625	25	
2-Cyclohexyl-4,6-dinitrophenyl acetate	100	88		500	93	
	50	63		250	70	
	25	50	27	125	59	106
	12.5	27		62.5	33	
Parathion	100	90		500	72	
	50	83		250	43	265
	25	70		125	26	
	12.5	45	12.5	62.5	15	
Aramite	500	95		5000	85	
	250	78		2500	78	
	125	48	112	1250	48	1100
	62.5	32		625	32	

CITRUS RED MITES.—Citrus mite eggs and adults were treated on orange fruits that had been partially coated with wax to restrict the area to be treated. All active stages of the citrus mite were removed with an air jet before the eggs were treated. Mortality counts for eggs were made after 5 days and for adults after 2 days. Against the adults parathion was again the most effective (Table 2). To achieve an LC-50 required 2.3 times as much 2-cyclohexyl-4,6-dinitrophenyl acetate, 6.8 times as much Aramite, and 13.1 times as much pentachlorophenyl acetate. In ovicidal tests all four compounds were relatively ineffective. Preliminary nonreplicated tests indicated that 0.5 per cent of parathion and 0.25 per cent of 2-cyclohexyl-4,6-dinitrophenyl acetate would be necessary to achieve a 50 per cent mortality of eggs.

Table 2.—Comparative toxicity of parathion, Aramite, and two esters of acetic acid to the citrus red mite (4 replicates).

Acaricide	Concentration	Mortality in 2 Days	LC-50
	Mg. per liter	*Per cent*	*Mg. per liter*
Pentachlorophenyl acetate	200	88	
	100	71	
	50	54	50
	25	26	
2-Cyclohexyl-4,6-dinitrophenyl acetate	50	95	
	25	82	
	12.5	68	8.8
	6.25	36	
Parathion	25	96	
	12.5	89	
	6.2	63	
	3.1	44	3.8
Aramite	100	85	
	50	64	
	25	51	26
	12.5	30	

PHYTOTOXICITY.—In phytotoxicity tests against five species of plants growing under natural conditions 2-cyclohexyl-4,6-dinitrophenyl acetate gave no injury when used as a 1 per cent spray, whereas pentachlorophenyl acetate caused moderate injury to beets, peas, and barley, severe injury to chard, and slight damage to collards.

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Vorticella Infestation of *Anopheles atroparvus* Larvæ[1]

DON W. MICKS, *Laboratory of Medical Entomology,*
University of Texas Medical Branch, Galveston

Several years ago we reported (Micks 1950) the lethal effect of a peritrichous ciliate, *Vorticella microstoma* Ehrenberg, on *Anopheles quadrimaculatus* larvae. Practically all larvae died in the fourth instar with very few reaching the pupal stage. Microscopic examination of the larvae revealed them to be covered with large masses of *Vorticella*. Death was apparently due to the inability of the larvae to remain on the water surface, thereby interfering with respiration. Experimental attempts to produce death in culicine larvae (*Aedes aegypti* and *Culex fatigans*) with this ciliate were uniformly unsuccessful.

The purpose of the present note is to report similar observations with a colony of *Anopheles atroparvus* maintained in the

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FIG. 1.—*Vorticella*-infested *Anopheles atroparvus* pupa with attached head capsule.

insectary at the Institute of Zoology, University of Pavia, Pavia, Italy. This colony was kept in the same room with colonies of *Culex molestus* and *C. fatigans* and many generations were reared through without incident. During the month of April, however, dead and dying fourth stage *A. atroparvus* larvae were found in many of the rearing pans. Microscopic examination of a number of these specimens revealed large numbers of *Vorticella* (species unknown) attached to all parts of the integument, as previously noted in the *A. quadrimaculatus* larvae. However, there was one interesting effect of this ciliate on *A. atroparvus* pupae not previously noted by us. When the *Vorticella*-infested larvae survived sufficiently long to pupate, pupation was almost always incomplete, with the head capsule of the larva remaining attached to the pupa (Fig. 1). These pupae lived as long as 24 hours with the attached head capsule. Whether the inability of the larvae to molt completely was due to direct or indirect effects of the ciliates is not known. Several attempts to establish them in pans of *C. molestus* and *C. fatigans* were unsuccessful.

These results are in accord with those of our previous work. Our observations are not in agreement with those of Jettmar (1947) who noted that a large number of *Culex fatigens* larvae collected from a pond in Shanghai were heavily infested with *Vorticella*. It should be pointed out, however, that Jettmar found that these larvae had suffered a severe invasion by streptobacilli and that they were secondarily invaded by *Vorticella*.

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Effect of Oil and Parathion Sprays on Soluble Solids of Oranges[1]

A. W. CRESSMAN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The effect of oil sprays on fruit quality of citrus is one of the major objections to their use. Harding (1953) found that oil emulsions applied in June and August in Florida decreased the total soluble solids of the juice whereas parathion plus wettable sulfur did not lower them and sometimes caused a slight increase. Bartholomew *et al.* (1951) reported that oranges in California sprayed with light-medium oil were generally lower in soluble solids than fruit sprayed with DDT or parathion, but Riehl & Wedding (1953) showed that the oil effect depended on the time of application.

Combinations of oil and parathion are very effective against California red scale, *Aonidiella aurantii* (Mask.), but are more liable to cause injury than the same oils alone (Cressman *et al.* 1950). In experiments conducted from 1949 through 1952 to develop a safer combination, a special light petroleum fraction was found to be just as effective as light-medium to heavy-medium oils in combination with parathion. Fruit from plots in a number of groves was analyzed for soluble solids and acids in order to determine the effect of the special light and heavier oils and parathion alone.

Table 1.—Effect of insecticides on percent of soluble solids in oranges.

GROVE[a]	DATE SPRAYED	MEDIUM OIL	SPECIAL LIGHT OIL + PARATHION	NON-OIL[b]
1	Oct. 5, 1949	11.2	12.0	12.1
2	Oct. 11, 1949	12.8	13.8	—
3	Oct. 27, 1949	13.0	13.4	13.4
4	Oct. 27, 1950	11.5	12.1	12.2
5	Nov. 17, 1950	11.4	—	12.4
6	Dec. 2, 1950	11.8	12.3	—
7	Oct. 9, 1951	—	12.8	13.0
8	Oct. 8, 1952	—	12.8	12.8
9	Nov. 1, 1952	13.6	14.8	—
10	Mar. 18, 1953	12.6	12.6	12.6

[a] Groves 7 and 8 had been sprayed with parathion the preceding year, and the others with oil.
[b] The non-oil plots in groves 1 and 5 were untreated; the others were sprayed with parathion.

MATERIALS AND METHODS.—The light-medium and medium oils used met the specifications of the California Department of Agriculture (Cox 1938). The special light oil had a Saybolt viscosity of 50 to 52 seconds and an unsulfonatable residue of 91 to 92 per cent. Initial boiling points of different lots ranged from 529° to 536° F., and the percentage distilling at 636° from 76 to 83 per cent. All lots had a lower boiling range than any of the light oils registered for use in California. Oil concentrations varied from 1.0 to 1.8 per cent. The parathion was a 25 per cent wettable powder and was used at 0.5 to 1 pound per 100 gallons with oil and at 1.5 to 2 pounds per 100 gallons alone. The sprays were applied by commercial spray crews, some by hand and some with oscillating boom.

Most of the experiments had objectives additional to the fruit-quality studies, and spray materials, size of the plots, and amount of replication varied according to the purpose of the experiment. The minimum plot size was 14 trees. In some experiments there was no replication of plots. Preliminary studies showed that differences in contour of the grove, or of soil or tree condition could cause larger differences in fruit quality than the insecticides, and thenceforth care was taken to select areas that were approximately level or of uniform slope, with trees of similar size and appearance. One test was made on navel oranges (grove 7, Table 1), the rest on Valencias.

Each fruit sample consisted of 36 oranges taken from 9 trees, 1 fruit from each quadrant. Two samples were taken from each plot. Valencia samples were picked the latter part of July or early in August, and the navels in January. Juice was extracted in a power reamer with oscillating strainer and freed of pulp by passage through a No. 90 cheesecloth. After de-aeration, soluble solids were determined with a Brix hydrometer and total acids by titration with sodium hydroxide.

RESULTS.—Comparisons of medium oil with and without parathion in four groves showed no effect of the parathion on soluble solids. Other comparisons are shown in table 1.

There was no measurable difference between plots treated with 1 per cent and 1.5 to 1.75 per cent of medium oil, nor between fruit sprayed with 0.5 and 1 pound of parathion per 100 gallons with oil. Therefore these concentrations were not separated in table 1. The average difference in soluble solids between the non-

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oil and medium-oil plots was 0.6 per cent, between the special light oil and medium oil 0.6 per cent, and between the non-oil and special light oil 0.1 per cent. The special light oil plus parathion did not cause any significant reduction in solids. The reduction of 0.6 per cent by a medium oil is in good agreement with the 0.7 per cent reported by Bartholomew *et al.* (1951).

Two other experiments were made in which Valencia oranges were sprayed in September with special light, and light-medium and medium oils. There was no difference in the soluble solids of the fruit, a result that was in line with Riehl's (1953) finding that oil sprays at this time caused little or no reduction in solids. The treatments had no consistent effect on maturity ratios.

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Toxicity of Several Antibiotics Administered by Injection to the German Cockroach[1]

JAMES N. LILES and FRANK W. FISK, *Department of Zoology and Entomology, The Ohio State University, Columbus*

Some investigations have been conducted concerning the effects of various antibiotics on insects. Steinhaus & Bell (1953) found several to be rather lethal to species of stored products insects, and Moffett (1953) found dihydrostreptomycin and streptomycin to be of significant value in the treatment of European foulbrood in the common honey bee, *Apis mellifera* L. In both and similar cases, the antibiotics were administered by adding them to the diet. Brues & Dunn (1945) administered penicillin to adult females of *Blaberus carniifer* Burm. via injection in an attempt to determine its effect on the roach's intracellular symbiotes. In our work injection was used exclusively.

METHODS.—Adult German roaches, *Blatella germanica* (L.), approximately 6 weeks old were employed in all cases. Both normal and chlordane-resistant strains were tested. Injection was accomplished by the standard method using a tuberculin syringe mounted in front of a micrometer head, with distilled water employed as the diluent for all of the compounds. The injection dosage varied between 1–2.5 μl, generally averaging 1.5 μl., per insect. LD_{50}'s were ascertained by graphing three or more points on logarithm-probit paper, each point being derived from the results of a test employing 20 insects. Mortality data were recorded 48 hours after injection.

RESULTS.—Table 1 is a list of the LD_{50} determinations. The values listed are for the normal strain only, but no significant differences in susceptibility were noted between strains.

Several tests which were designed to test for cumulative toxicity of injections were also carried out. These protocols were varied, but the results were always the same. No cumulative toxocity was noted; the sublethal dosages of antibiotic apparently being rapidly metabolized and/or excreted by the insect.

Table 1.—Approximate LD_{50}'s of several antibiotics administered to the German cockroach via injection.

ANTIBIOTIC	COMPANY	μg./COCKROACH	
		Male	Female
Dihydrostreptomycin sulfate	Squibb	38	50
Neomycin sulfate	Upjohn	27	60
Streptomycin sulfate	Squibb (Exptl.)	70	130
Terramycin HCl	Pfizer	90	165
Bacitracin	Commercial Solv. Corp.	100	235
Penicillin G, Na	Upjohn	350	400–500
Penicillin G, K	Bristol Labs.	300	400–500
Polymixin	Nutritional Biochemicals Corp.	11	23
Aureomycin[a]	Lederle	—	—

[a] Aureomycin was not soluble in greater concentration than three per cent solution. Males and females tolerated four 60 μg. injections, given every other day, with negligible mortality.

DISCUSSION.—The results of this investigation revealed extreme variability in the deleterious effects of different antibiotics to the German cockroach; the range between polymixin and penicillin being quite great. This may be directly due to the compounds themselves since they are, in general, quite different in chemical structure. In addition, some evidence is available that antibiotics may kill microörganisms by interrupting enzymatically controlled metabolic cycles. In such large dosages, the antibiotic might elicit the same effects upon the insect. Also, death may be due entirely to the various effects upon the intracellular symbiotes, gut flora and fauna of the cockroach.

It was interesting to note that no differences in mortality were recorded between the chlordane-resistant and normal strains of cockroaches.

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A Laboratory Dust Mixer[1]

R. T. GAST[2] and J. L. BRANN[3,4]

Studies on the effectiveness of insecticidal dust formulations often necessitate the actual mixing of the insecticide with various carriers. Investigating the effect of various carriers on the activity of parathion, the authors found it necessary to formulate

[1] Accepted for publication October 25, 1954.
[2] Assistant Research Professor now with N. C. State College, Raleigh.
[3] Associate Professor Entomology, Cornell University.
[4] Grateful acknowledgment is made for the helpful advice of the late Dr. L. B. Norton on the chemical analysis of parathion and DDT.

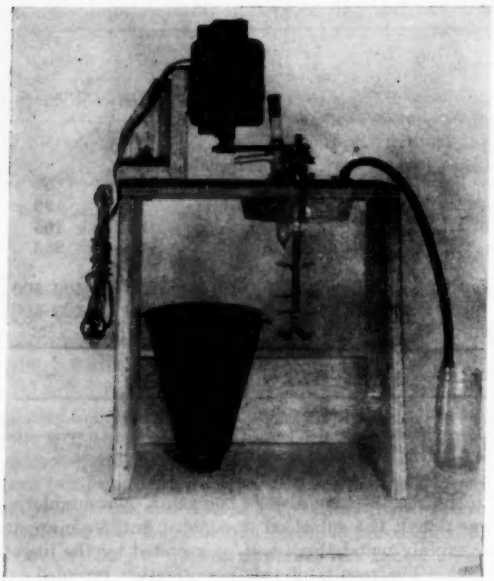

FIG. 1. Front view of mixer with glass sprayer in place.

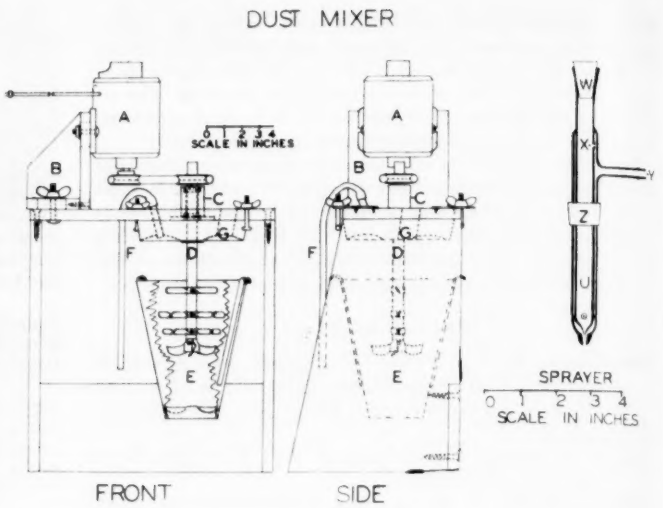

FIG. 2.—Diagram of mixer. A—Motor, B—Adjustable support, C—Ball bearing housing, D—Agitator shaft, E—Dust container, F—Air release tube, G—Hole for spray injector, U—Toxicant container, W—Stopper in loading hole, X—Hole connecting inner and outer chambers, Y—Air inlet, Z—Stopper to seal injector to mixer.

technical parathion with 28 different types of carriers. The use of a ball mill was undesirable because of the grinding action of the mill and subsequent reduction in particle size of the carrier. Solvent impregnation was also undesirable since the highly absorbent carriers would require much larger volumes of solvents than the low absorbent types.

A direct method of mixing the parathion with the carrier seemed best, and a mixer was constructed with the idea of spraying a mist of parathion into a cloud of the carrier. Further work showed that solid insecticides such as DDT could be used in the mixer if they were first dissolved in a small amount of solvent. By spraying the solution of the solid insecticide onto the dust, equal volumes of solvent could be used with the various carriers and still obtain good distribution of the toxicant in the formulation.

The mixer, a modified miniature of the Bean self-mixing dust hopper, was designed to hold 100 grams of formulation. It consisted essentially of a metal cone to hold the dust, a motor-driven blade-bearing shaft for agitation, and a spray injector to discharge the toxicant as a mist onto the agitated dust. (Figures 1 and 2).

The $\frac{1}{8}$ h.p. driving motor was run at 2700 r.p.m. and was connected to the agitator shaft by means of a rubber belt. The agitator shaft was supplied with four sets of dual pitched blades that produced a whirlpool motion in the dust. The portions of the blades nearest the shaft were pitched to direct the dust downwards while the pitch of the outer portions were reversed so as to direct the dust upwards. The bottom set of blades was set close to the bottom of the container, thus insuring that all portions of dust charge were thoroughly agitated. The top and bottom of the container were saucer shaped to facilitate the whirlpool motion.

The spray injector consisted of a double walled glass tube, the inner chamber containing the toxicant and the outer chamber containing air used in atomizing the toxicant. The bottom end of the inner tube was drawn into a fine tip with an opening of 0.5 mm. This was inserted into the reinforced tip of outer tube which had an opening of 0.9 mm. A small hole connected the inner chamber with the outer jacket and allowed for the air pressure to be equalized in both chambers. Air pressure of 15 p.s.i. was used to drive the toxicant from the inner chamber through the smaller inner tip opening while air coming from the surrounding chamber atomized the toxicant into a fine mist. Although the amount of air introduced into the mixing chamber was relatively small, it had to be released from the container in such a way as to prevent the loss of dust particles. This was accomplished by inserting a rubber tube through the top of the container and collecting any escaping dust in a small glass jar. Recovery of total charge (carrier plus toxicant) was never less than 99.9 per cent.

To make a formulation, a weighed amount of carrier was placed in the mixing chamber and the motor started. With the injector in place a measured amount of toxicant was pipetted

Table 1.—Per cent recovery of parathion from different samples of a 15 per cent formulation.

SAMPLE NO.	PER CENT RECOVERY[a]	DEVIATION FROM MEAN
1	14.61	0.01
2	14.80	0.20
3	14.82	0.22
4	14.73	0.13
5	14.63	0.03
6	14.46	−0.14
7	14.45	−0.15
8	14.66	0.06
9	14.54	−0.06
10	14.55	−0.05
11	14.40	−0.20
Av.	14.60	

Standard Deviation: 0.13.

[a] The recovery of pure parathion was expected to be slightly less than 15 per cent because the parathion was a technical grade which contained a small amount of impurities.

Table 2.—Per cent recovery of DDT from different samples of a 15 per cent formulation.

Sample No.	Per Cent Recovery	Deviation from Mean
1	14.63	0.30
2	14.13	−0.20
3	14.49	0.16
4	14.37	0.04
5	14.31	−0.20
6	14.25	−0.08
7	14.42	0.09
8	14.33	0.00
9	14.22	−0.11
10	14.19	−0.14
Av.	14.33	

Standard Deviation: 0.15.

into the inner chamber, and the air turned on. After the toxicant was discharged into the chamber, the mixer was run an additional 30 seconds to give better mixing. With light, highly absorbent carriers, this procedure gave good mixing, but low absorbent carriers tended to cake slightly. To assure homogeneous formulations, all material was emptied onto a paper and any caked material was brushed from the container onto the pile. Dust caught in the dust trap bottle, generally less than 0.5 gram, was also added. With the empty tank in place and the agitator turning, the formulation was poured slowly back into the mixer through the hole previously occupied by the spray injector. By this means, all lumps were broken up and the toxicant evenly distributed throughout the mixture.

With liquid materials such as parathion or nicotine, the pure or technical material could be used directly in the injector, but solid materials such as DDT would first have to be dissolved in a solvent. The solvent should be capable of holding at least 50 per cent of its weight of insecticide and should not be excessively volatile since too rapid evaporation would leave deposits of insecticide on the spray injector. With DDT, for example, cyclohexanone was found to be better than either acetone or ether. For best results the dust in the mixer should not become saturated with the solvent. After the impregnation, the formulation should be spread on a glass plate to allow for the evaporation of the solvent. With the solvent completely evaporated, the formulation should be poured slowly into the running mixer to break up any caked material.

Parathion was formulated as a 15 per cent powder with 28 different carriers of various types. Of these, gypsum proved to be the most difficult to mix evenly. A formulation of gypsum was, therefore, used to test the homogeneity of the mixtures on the assumption that it was the poorest mixture of the group. Eleven 1½-gram samples were taken from this mixture and analyzed for their parathion content. The analyses for the parathion were made by a direct measurement of an extract of the sample with an ultraviolet spectrophotometer.[5] The results are shown in table 1.

In a similar manner, a formulation of DDT was made up with gypsum using cyclohexanone as the solvent and analyzed for the DDT content (Table 2).

From the results of these tests it was concluded that the mixing obtained with this apparatus was adequate, since the variations in different portions of the formulations was well below measurable differences obtained in biological tests.

[5] Hirt, R. C., and J. B. Gisclard. 1951. Determination of Parathion in air samples by ultraviolet absorption Spectroscopy. Analytical Chem. 23: 185.

Chemical Impairment of Development in House Flies[1]

Milton S. Konecky[2] and Norman Mitlin,
Entomology Research Branch, Agr. Res. Serv., U.S.D.A.

A fresh approach to the chemical control of insects using criteria other than the conventional knockdown or kill for the measurement of insect response to chemicals has been initiated.

These experiments were set up primarily to measure the indirect effects of chemical compounds on house flies, *Musca domestica* L., rather than direct kill. However, many compounds were found that at certain concentrations completely inhibited larval development. The effects of the compounds on the pupae and on the reproductive ability of the adults that emerged were also measured. The screening method developed for this purpose by Mitlin *et al.* (1954) was used. This method consists in inoculating with house fly eggs CSMA (Chemical Specialties Manufacturing Association) rearing medium (Anonymous 1953) treated with the test chemical and determining the viability of eggs taken from the adults that emerge from this medium. Observations are made during the entire developmental cycle, and effects differing from controls are noted. The length of larval and pupal life and the number of adults emerging are recorded. In the present study the selection of test chemicals was based upon three lines of attack.

The first line of attack was the use of mitotic poisons, chemicals that impair cell division (Loveless & Revell 1949). Wallace (1952) has shown that in *Drosophila* the proportion of viable fertilized eggs is decreased by treatment with nitrogen mustards. This action parallels the well-known sterilizing effect of X rays in *Drosophila*. Bushland & Hopkins (1953) sterilized the pupae of screw-worms, *Callitroga hominovorax* (Coq.), with X rays and gamma rays.

The second line of attack was the use of chemical antimetabolites. Goldsmith & Harnley (1950) have reported adverse effects in development in *Drosophila* on treatment with antimetabolites, notably the folic acid antagonist aminopterin (4-aminopteroylglutamic acid). Mitlin *et al.* (1954) have shown the same adverse response to aminopterin by the house fly.

The third line of attack was the testing of chemicals that had shown some previous form of biological activity such as repellent, insecticidal, synergistic, or bactericidal.

The effects of these compounds tested at different concentrations are shown below.

Compounds showing delayed pupation or decreased emergence.

Compound	Concentration (Per Cent/ Weight)	Excess Number of Days to Pupation[a]	Per Cent[b] Emergence
Mitotic poisons:			
Phenyl urethan (ethyl carbanilate)	0.25	1	None
Urethan (ethyl carbamate)	0.125	—[c]	63
MBA-nitrogen mustard [N,N-bis(2-chloroethyl) methylamine hydrochloride)]	0.25	2	3
	0.0215	1	48
Antimetabolites:			
Sulfanilamide	0.25	—[c]	18
Pival (2-pivalyl-1-indanedione)	0.0625	4	16
	0.0313	4	2
Sodium salt of pival	0.0313	3.5	33
p-Nitrophenol	0.25	2	None
Benzimidazole	0.25	3	43
p-Nitrobenzoic acid	0.25	—[c]	10
Previous biological activity:			
Menadione (2-methyl-1,4-naphthaquinone)	0.125	4	11
	0.0063	1.5	25
Piperonyl butoxide	0.11	1	28

[a] Represents difference between experimental runs and the several control runs; length of larval period of controls ranged from 6.5 to 8.5 days.
[b] Based on emergence in controls. [c] No effect.

[1] Accepted for publication October 25, 1954.
[2] Present address, Chemistry Department, University of Illinois, Urbana, Illinois.

Compounds showing complete inhibition of larval development at concentration indicated (per cent/weight).

Compound	Lowest Effective Concentration
Mitotic poisons:	
Podophyllotoxin	0.122
Urethan	0.25
Phenyl urethan	0.50
Antimetabolites:	
Pival, sodium salt	0.063
Pival	0.125
Coumarin	0.25
Sulfanilamide	0.50
p-Nitrophenol	0.50
Thiourea	0.025
Previous biological activity:	
Thiophosphoramide 669 (N-2-carboxyethyl diethyl phosphoramidothionate)	0.013
Pyridine	0.125
Phenothiazine	0.25
Menadione	0.25

	Lowest Concentration Tested
Mitotic poison: Colchicine	0.063
Antimetabolite: Sodium salt of valone (2-iso-valeryl-1,3-indanedione)	0.0313
Previous Biological Activity:	
Thiophosphoramide 657 (N-carbethoxymethyl diethyl phosphoramidothionate)	0.0063
L-13/59 (0,0-dimethyl 2,2,2-trichloro-1-hydroxyethylphosphonate)	0.0079
Diazinon	0.0313
Quaternary ammonium salt [N-(caprylco-lamino-formylmethyl) pyridinium chloride)]	0.0313

Compounds showing no apparent effect at maximum concentration tested, 0.25 per cent.

Antimetabolite: 2-Amino-5-chlorobenzoic acid
Previous biological activity:
Rotenone
Urea
N-butyl acetanilide

No decrease in egg viability was observed for any of these compounds. More extensive studies on individual chemicals are in progress. It is indicated from these results that measurements other than knockdown and kill can and should be used as criteria in the search for chemicals to control insects. The use of mitotic poisons and antimetabolites may be a fruitful approach to solving the problem of chemical control of insects. The foregoing data are the result of initial screening tests and are presented now because the results to date appear very promising.

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Ovicidal Action of Malathion on Grape Leafhopper Eggs[1]

M. M. Barnes and C. R. Ash, *University of California Citrus Experiment Station, Riverside*

Malathion is extensively used for control of grape leafhoppers in California vineyards, especially where the development of resistance has precluded satisfactory use of DDT (Stafford & Jensen 1953). A 4 per cent malathion dust with or without 25 to 50 per cent sulfur, the latter for mildew control, is ordinarily applied at 20 pounds per acre.

When applied under satisfactory conditions, such applications quite generally result in 99 to 100 per cent mortality of nymphs and adults. It should be noted, however, that initial kill is unsatisfactory during cool weather. For example, a 4 per cent malathion dust at 25 pounds per acre applied in early morning during a period when temperatures ranged from 45° to 50° F. provided an excellent deposit on vines wet with dew, yet resulted in but 82 per cent reduction of adults after 5 days during which daily maxima were 71° F. or lower. When applied during warmer periods against high adult, nymph and egg populations not only is initial mortality of adults and nymphs virtually complete, but resultant extended control is frequently attained which is related either to residual action against newly hatched nymphs or ovicidal action, or both. Eggs of the grape leafhopper are entirely inserted between the upper and lower leaf epidermis and are thus not exposed to direct contact by dust particles, being protected by the epidermis and to some degree by mesophyll tissue. The average incubation period for leafhopper eggs in the greenhouse at a mean temperature of 77° F. is 17 days, ranging from 14 to 20 days. Since it seemed unlikely that the residual effect of malathion dust deposits on newly hatched leafhoppers would extend for such periods of time, and since newly hatched nymphs are not observed in numbers commensurate with estimated egg populations during the 3-weeks' period following dust applications in high populations, the possibility of an ovicidal effect on the eggs was investigated.

Bench grown Mataro grapevines were pruned back to seven leaves and each infested with 250 leafhoppers (*Erythroneura variabilis* Beamer) for a 5-day period after which the leafhoppers were removed. Such infestation resulted in deposition of an average of 67 eggs per leaf as ultimately determined. Two of these vines were then dusted with a 4 per cent malathion dust[2] with a laboratory duster. The latter unit is equipped with a centrifugal fan and provides a dust laden air stream in which the vines were rotated for 10 seconds. This provided a uniform dust deposit on both sides of the leaves which, though somewhat heavier than that obtained on dry foliage in the vineyard, was not excessive. Treated and untreated vines were then placed in a greenhouse section maintained at an average temperature of 77° F. Black paper collars bordered with *Deadline* were placed around the base of each vine. When leafhopper nymphs began hatching on the untreated-vines 14 days after initial infestation, 9 days after removal of the leafhoppers, one of the previously untreated vines was dusted with 4 per cent malathion in the same manner. This was done to see whether any effect which

[1] Accepted for publication November 1, 1954.
[2] Supplied by the American Cyanamid Company.

Table 1.—Mortality of grape leafhopper eggs in grape leaves dusted with malathion.

VINE	TREATMENT	TOTAL NO. OF NYMPHS	NO. OF EGGS IN 3 LEAVES[a]	NO. NYMPHS	PER CENT HATCHED
1	None	447	364	309	84.9
2	None	252	195	170	87.2
3	None	359	334	270	80.8
4	4% malathion dust	2	295	2	0.7
5	Eggs 1–5 days old	0	374	0	0
6	4% malathion dust Eggs 9–14 days old	1	139	1	0.7

[a] In the case of the checks, selecting three leaves from which the greatest number of nymphs emerged.

malathion might have would be influenced by the average age of the eggs.

Counts were made daily of the number of newly hatched leafhopper nymphs on each leaf and the nymphs removed. Very few nymphs were found on the paper collars, dislodged from the untreated leaves, and none were found dislodged from treated foliage. After hatching was complete, the number of eggs in three leaves from each vine was determined in the following manner. Each of the grape leaves to be examined was placed in boiling water for approximately 30 seconds and then transferred to a boiling 95 per cent alcohol solution where the leaf remained until all the chlorophyll was leached out. The leaf was again placed in boiling water for a few seconds in order to return it to a flaccid state and then transferred to a water-filled petri dish. It was not found necessary to carry out the dyeing procedures as outlined by Curtis (1942) since the eggs of the grape leafhopper are apparent when the leaf is examined with transmitted light under a binocular microscope. The eggs were found to lie parallel and within the tissue immediately adjacent to the larger veins of the somewhat thin leaves of bench grown vines of the Mataro variety, occasionally being inserted in the veins. Leaf tissue is somewhat discolored adjacent to hatched eggs so that the location of these was readily apparent. Half of the eggs in leaves dusted soon after removal of the adults showed some development while 85 per cent of those in leaves treated when hatching began showed well developed embryos, though virtually all failed to hatch. As shown in table 1, less than 0.5 per cent of the eggs in leaves dusted with malathion hatched, while an average of 84 per cent of the eggs in the untreated foliage were viable.

While the conditions of this trial differ from those encountered in the field in several ways, nevertheless these results indicate that ovicidal action by malathion dust applications may occur to some extent in the field. This may explain in part the failure of leafhopper nymphs in some instances to appear in significant numbers during the 3-week period following applications of malathion dust against high populations of all stages of leafhoppers.

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Lindane Applied in Liquid Floor Wax for Control of Silverfish (Thysanura)[1]

W. E. BECKEL[2]

For the last few years a considerable infestation of silverfish has been prevalent in the camp at Ft. Churchill, Manitoba. Successful control is in progress at the breeding sites but the constant application of an insecticide to the corridors and the individual quarters has been difficult. As a means of relieving this situation, Major L. E. Macdonald of the Canadian Corps of Engineers suggested to the author that lindane mixed in the liquid floor wax might act as a method of control provided it did not produce unsightly floors or harm humans. The present paper gives the results of a trial designed to test this suggestion.

MATERIALS AND METHODS.—Two experimental floor areas were designed, each with tiles laid on plywood. One was waxed and polished daily, one-half with a mixture of 1 per cent lindane in oil and liquid floor wax, the other half with a mixture of 1 per cent lindane wettable powder in liquid floor wax. The other square was waxed and polished once, one-half with the 1 per cent lindane in oil and wax, the other half with 1 per cent lindane wettable powder and wax.

At intervals during the trial 10 silverfish were placed in a belljar on each half of the square which had the one application of wax and insecticide. The belljars were open at the bottom to the waxed tile. The periods of time necessary for total kill were recorded. On three occasions during the trial the test area was rubbed with the soles of the experimenter's boots to simulate normal use of the floor.

RESULTS AND DISCUSSION.—The experiment was continued only for 2 weeks. There was no difference in the amount of time necessary for kill by the lindane in oil or the wettable powder. The time necessary for total mortality of the 10 silverfish in each belljar indicated that there was a lengthening of the time necessary to kill the insects as time passed. This was shown by the fact that 1 or 3 days after treatment only 25 minutes were required for total mortality and at 5 or 8 days after treatment ½ hour was required, whereas at 11 or 14 days after treatment a period of 1½ hours of release on the treated tile was required for total mortality.

An odor which might be considered objectionable was given off from the area waxed with the mixture of lindane in oil and wax. There was no odor when wettable powder was used. No diminution of shine was detected between the area treated daily with the wax and insecticides and an untreated floor.

Of considerable value would be information on how long a silverfish must be in contact with a floor treated with 1 per cent lindane in floor wax to be killed if, after contact, it moves to an untreated area. These experiments are now being carried out. Preliminary trials indicate that a freshly waxed floor will kill insects if they are on it for from 2 to 5 minutes.

The 1 per cent level of concentration was chosen to minimize the possibility of harmful effects of the insecticide on children with bare skin coming in contact with the floor. A higher concentration might prove to be harmless and yet capable of killing insects with less time of contact. However even with 1 per cent considerable control can be expected since the floors in camp are usually waxed weekly or more frequently.

[1] Accepted for publication November 12, 1954.

[2] Defence Research Northern Laboratory, Ft. Churchill, Manitoba. Acknowledgment is made to the Defence Research Board, Department of National Defence, Canada, for permission to publish this note.

The Effect of Alfalfa Irrigation Treatments on the Two-Spotted Spider Mite in Alfalfa[1]

GEORGE D. BUTLER, JR., *University of Arizona Agricultural Experiment Station, Tucson*

Preliminary observations in 1951 of infestations of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, in an alfalfa irrigation experiment near Yuma, Arizona, showed wide variations in mite populations between plots receiving different amounts of moisture. This is a report of further observations, made in the same area during 1952, on the effects of variations

[1] Arizona Agricultural Experiment Station Technical Paper Number 348. Accepted for publication November 15, 1954.

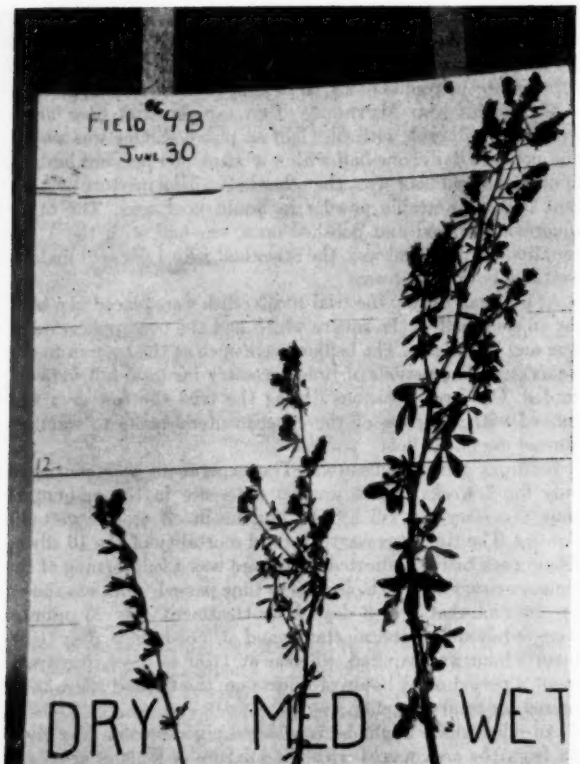

FIG. 1.—Relative growth of alfalfa plants from plots receiving "dry," "medium," and "wet," irrigation schedules respectively. Yuma, Arizona, June 30, 1952.

in irrigation frequencies upon mite populations. The negligible natural rainfall in the Yuma area averages less than three inches per year and the crops are entirely dependent on water received by irrigation.

In 1952 observations were made in a field of Chilean 21-5-5 alfalfa 2 years old having a clay-loam soil with a high water table and located on the valley floor of the Colorado River. The field was divided into 12 areas, each separated by ridges, and subjected to three schedules of irrigation, each replicated four times in randomized blocks. These irrigation schedules were designated as "dry," "medium," and "wet," respectively. All plots were thoroughly irrigated on March 28, 1952, at the start of the observations. The "dry" plots received no further irrigation during the period of the experiment. The "medium" plots were irrigated at intervals of 3 weeks until the observations ended on July 15. The "wet" plots were irrigated at 10-day intervals during this same period. On May 20, when the alfalfa was cut for hay, there were no marked growth differences between the plants receiving different irrigations nor had any important mite populations developed. Marked differences among the three irrigation levels appeared, however, in the subsequent alfalfa regrowth. (Figure 1.)

Table 1.—Effect of irrigation treatments on the number of two-spotted spider mites on the basal leaves from 100 alfalfa stems. Yuma, Arizona. 1952

TREATMENT[a]	NUMBER OF MITES ON			
	June 24	July 1	July 8	July 15
Dry	0	2	10	0
Medium	73	37	268	304
Wet	84	208	344	1024

[a] All plots were irrigated on March 28. Dry plots received no further irrigation. Medium and wet plots were irrigated at intervals of 21 and 10 days, respectively, during the observation period. Each treatment was replicated four times.

The first measurements of mite populations were made on June 24, since earlier infestations were too insignificant for measurement. Mite populations were determined by counting the actual numbers of mites present on the large basal leaves on 100 main stems from plots receiving each irrigation schedule. The actual counts were made in the field, with the aid of a 10X headband magnifier, on June 24, July 1, July 8 and July 15, 1952, and are summarized in table 1.

By June 24 a trend had begun which soon developed into large differences in mite populations among the three irrigation schedules. Plants in the "wet" irrigation plots had the most mites. Infestations were lower in the "medium" plots and were lowest in the "dry" plots.

The influence of the different irrigation schedules upon mite populations is believed to be both ecological and nutritional. The sparse growth of the alfalfa in the "dry" irrigation treatment allowed the sunlight to penetrate to the ground surface. Temperatures of the air were sometimes 10 degrees higher 7 inches above the ground in the "dry" irrigation plots and relative humidities were very much less.

These variations in ecological conditions, together with the different amounts of soil moisture available, greatly influenced alfalfa plant growth. Measurement of stem length, number of leaves, number of blooms and other growth characteristics showed marked differences according to the irrigation treatments. It is postulated that the availability or quantity of plant nutrients varied between the hardened, sparse growth of the "dry" irrigation plots and the lush growth of the "wet" irrigation plots and caused correspondingly marked variation in mite populations.

Systox for Control of the Leafhopper Vector of Cranberry False-Blossom[1]

MARTIN T. HUTCHINSON

False-blossom has been a particularly serious virus disease in New Jersey because the climate is highly suitable for the building up of large populations of its leafhopper vector, *Scleroracus vaccinii* Van D. (*Euscelis striatulus* Fallen), commonly known as the blunt-nosed cranberry leafhopper. The virus ultimately prevents fruit set on affected cranberry plants, and it has been considered responsible for marked reductions in New Jersey cranberry yields. Measures to control the leafhoppers have included late holding the winter flood until July to kill the overwintering eggs; temporary flooding during the growing season to drown the nymphs, and spraying or dusting with either pyrethrum or DDT to kill the nymphs and adults. Observations made in New Jersey during 1954 indicate that the systemic phosphate insecticide Systox (demeton) may also be of value in controlling this insect.

MATERIALS AND METHODS.—In mid-April of 1954, eight cranberry plants (var. Early Black), infected with false-blossom virus, were treated with Systox emulsion to eliminate an infestation of two-spotted spider mites. The plants were separately

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, The State University of New Jersey, Department of Entomology, New Brunswick. Presented at the meeting of the Eastern Branch of the Entomological Society of America held in New York, N. Y., November 15-16, 1954. Accepted for publication November 18, 1954.

Table 1.—**Effect on the blunt-nosed cranberry leafhopper when confined to cranberry plants grown in soil treated with Systox.**

Treatment of Plants	Adult Leafhoppers Introduced											
			Number Present After (Days)									
	Number	Date	3	4	6	7	8	10	11	13	14	18	21
Treated plant[a]	15	Aug. 6		0	0			0				0	0
Treated soil[b]	15			0	0			0				0	0
Untreated[c]	15			7	5			5				5	1
Treated plant	59	Aug. 24	0		0		0	0			0		
Treated soil	59		17		2		0	0			0		
Untreated	59		25		24		24	24			24		
Treated plant	40	Aug. 27	2	0		0			0	0			
Treated soil	40		18	16		7			3	2			
Untreated	40		29	29		29			22	14			

[a] Plant removed from treated soil, washed free of soil, and potted in untreated soil on Aug. 4.
[b] Untreated plant potted in treated soil on Aug. 4.
[c] Untreated plant potted in untreated soil on Aug. 4.

potted in 6-inch pots containing the black, sandy-peat, acid soil common to cranberry bogs. A total of about 1 quart of Systox emulsion was applied to the soil at a concentration of 1½ to 2 pints of 23 per cent emulsion concentrate per 100 gallons of water.

On July 7, 1954, a total of about 600 leafhoppers was allowed to feed on the eight cranberry plants. All of the leafhoppers were found dead when first checked on July 29. From three untreated cranberry plants, a total of 120 live leafhoppers was recovered. Because this result indicated that Systox was still effective after 3 months, a series of tests was begun to determine whether the Systox was residual in the plants, in the soil, or in both.

The cranberry plants were separated from the treated soil, and the roots were carefully washed. Then they were repotted in untreated soil. Untreated cranberry plants of the Early Black variety were then potted in the treated soil. As a check, untreated Early Black plants were potted in untreated soil. In the latter case, the plants were of the same age and vigor as those potted in the treated soil, and the soil used was similar to that used in repotting the treated plants. Leafhoppers were then fed on these three groups of plants at varying intervals.

RESULTS.—The results of testing three replications of the above series of plants are given in table 1 and show that the treated plants remained toxic to leafhoppers for more than 4 months. The treated soil, after the same period, was partially effective in rendering previously untreated plants toxic to the leafhoppers.

DISCUSSION.—This unforeseen residual action of Systox in the cranberry plant may very possibly have a practical application. If a foliar spray is as satisfactory as a soil drench appears to be, and if the amount of material required per acre is not excessive, treatment of newly planted cranberry bogs with Systox to eliminate the blunt-nosed cranberry leafhopper for a year would be well worth attempting. The fact that berries are not generally harvested until the third year after planting would probably give adequate time for the Systox to be rendered non-toxic, particularly since cranberry bogs are flooded during the winter months.

At the same time, infestations of the cranberry scale, *Aspidiotus oxycoccus* Woglum, would probably be discouraged, because foliar sprays of Systox have given fair control of this insect. The effect if any, on the numerous chewing pests of cranberry is yet to be determined. However, if one Systox spray were timed to coincide with the spring application against fireworms (*Rhopobota vacciniana* Pack and *Peronea minuta* Rob.), the *Sparganothis fruitworm* (*Sparganothis sulfureana* Clem.), the blossom worm (*Epiglaea apiata* Gr.), and the tipworm (*Dasyneura vaccinii* Smith), it is possible that all of these pests could be reduced to uneconomic levels as well as controlling the scale and the leafhopper. At present, several heavy applications of DDT are used to control all of the above insects except the scale, for which malathion or Metacide is recommended.

SUMMARY.—Cranberry plants, exposed to soil applications of Systox (demeton), remained toxic to the blunt-nosed cranberry leafhopper (*Scleroracus vaccinii* Van D.) for more than 4 months.

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Tests of Toxaphene, Chlordane, and Strobane against the Lone Star Tick on Cattle[1]

H. M. BRUNDRETT, ROWLAND RICHARDS, and C. L. SMITH,
Entomology Research Branch, Agr. Res. Serv., U.S.D.A.

Recent toxicological studies have shown that the chlordane available since 1951 is less toxic to mammals than that produced earlier (Ingle 1953, Radeleff *et al.* unpublished). The question therefore arose as to whether it was as effective against the lone star tick, *Amblyomma americanum* (L.), on cattle. Since the older product had been found to be about as effective as toxaphene (McDuffie *et al.* 1950), in 1954 an experiment was conducted to compare the new chlordane with that insecticide. Tests were also made with Strobane, which preliminary tests in 1953 had shown to equal toxaphene.

The new chlordane, Strobane, and toxaphene were formulated into emulsion concentrates containing 50 per cent of technical insecticide, 40 per cent of kerosene, and 10 per cent of CTX 54.[2] The concentrates were diluted with water to make 0.5 per cent emulsions, which were applied with a power sprayer at the rate of approximately 2 gallons per animal. The results are given in table 1.

[1] Accepted for publication November 19, 1954.
[2] A blend of emulsifiers manufactured by Wm. Cooper & Nephews, Inc., Chicago, Ill.

Table 1.—Numbers of adult lone star ticks per animal before and at various intervals after spraying with 0.5 per cent emulsions of toxaphene, chlordane, and Strobane.

Spray Date and Insecticide	Before Spraying			After 7 Days[a]		After 14 Days		
	Flat	Partly Engorged	Engorged	Flat	Partly Engorged	Flat	Partly Engorged	Engorged
March 8								
Toxaphene	11.9	1.2	0.0	13.3	0	9.7	0.2	0
Chlordane	14.1	1.7	0.1	5.2	0.1	9.4	0.1	0
Strobane	14.0	1.0	0.2	9.9	0	15.9	0.2	0
April 5								
Toxaphene	36.7	10.5	2.3	9.3	0	34.1	3.3	0.5
Chlordane	20.3	3.8	1.1	10.3	0	37.8	3.6	0.5
Strobane	26.1	3.3	2.1	9.5	0	37.5	2.2	0.4
April 28								
Toxaphene	27.4	4.2	2.2	8.8	0	29.0	3.6	0
Chlordane	13.2	5.0	0.8	7.4	0	20.4	1.8	0
Strobane	36.6	4.0	0.6	15.6	0	31.5	2.6	0
Average								
Toxaphene	25.3	5.1	1.5	10.4	0	24.2	3.3	0.1
Chlordane	15.8	3.5	0.7	7.9	0	22.5	1.8	0.1
Strobane	25.5	2.7	0.9	11.6	0	28.3	1.7	0.1

[a] No engorged ticks.

The tests were conducted during March, April, and May on Hereford cattle from the government herd maintained near San Antonio, Texas. In the first and second series of tests 9 or 10 animals, including some calves, were treated with each insecticide, but in the third series only 5 were used. The cattle were heavily infested with ticks at the time of treatment, and afterward were placed together in the same pasture to insure equal pressure of reinfestation. Since the pasture was heavily infested with ticks throughout the tests, the results reflect the effectiveness of the insecticides under severe conditions.

After treatment the animals were examined daily for the first 3 days and twice weekly thereafter. Practically all the flat ticks were killed within 24 hours. Most of the partly engorged and engorged ticks were affected within 24 hours, but after 48 hours these stages had either dropped off or died on the host. All three treatments gave practically complete control within 48 hours, and little or no reinfestation occurred until the fifth day after treatment.

Although the three insecticides provided equally good immediate control, none of them prevented reinfestation for as long as 1 week. After this time there were nearly half as many flat ticks as before treatment but no partly engorged stages, an indication that the ticks had been attached only a day or two. After 14 days the infestation was about equal to that before treatment.

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Garden Webworm Control on Corn[1]

Eugene W. Hamilton and Roscoe E. Hill, *Nebraska Agricultural Experiment Station, Lincoln*

Garden webworms, *Loxostege similalis* (Guen.), were unusually abundant in southeastern Nebraska during the summer of 1954. Lighter infestations were present westward and south of the Platte River and over a good portion of the northeastern part of the state. Most serious damage was in alfalfa, but corn and soybeans also suffered. Late-planted corn in lower areas along creek bottoms in some cases was completely destroyed. Many other cornfields were moderately to severely damaged.

Table 1.—Number of garden webworms 25–30 hours after treatment. Lincoln, Nebraska, July 4, 1954.

Treatment and Pounds per Acre	Number of Webworms[a]
Toxaphene, 2	9.5
DDD, 2	7.0
Endrin, 0.4	5.0
Aldrin, 0.5	12.5
Untreated	15.2
L.S.D. at 5% level	4.9

[a] Average population on 10 plants per plot.

Nebraska has experienced two other webworm outbreaks in recent years; in 1947, the first for many years, and again in 1949. Although garden webworms have been reported from scattered areas since those dates the damage and extent of the infestations have been unimportant until the heavy general outbreak of the 1954 season.

Hixson & Muma (1950) found that an emulsion spray of DDT, 1 pound per acre, or a BHC suspension spray containing ½ pound of the gamma isomer per acre, gave significant control of garden webworms on corn. Chlordane as a dust or emulsion and DDT as a dust at 1 pound, piperonyl butoxide-pyrethrum at 10 pounds and toxaphene dust at 1 pound per acre did not give adequate results. Numerous workers in other states since have indicated toxaphene at 2 pounds per acre would give good control and during 1954 this was the recommended control measure in Nebraska. Generally the results obtained by our farmers were good. Hamman & Nelson (1954) recently reported that endrin gave excellent control of the closely related beet webworm, *Loxostege sticticalis* (L.)

The 1954 garden webworm infestation provided an opportunity to obtain additional information on the effectiveness of some newer insecticides against this species. Consequently, toxaphene and DDD each at 2 pounds per acre, endrin at 0.4 pound, and aldrin at 0.5 pound per acre, were tested on a uniformly, although somewhat lightly, infested plot of corn at Lincoln. Treatments were made on July 3. All chemicals were replicated four times and applied with a 3-nozzle per row power sprayer at 40 pounds pressure in 60 gallons of water per acre. Plots were four rows wide and 50 feet long.

Population counts taken July 4 are shown in table 1. The number of webworms was counted on 40 plants for each treatment or on five plants from each of the two middle rows in each plot. By July 6 the infestation apparently had been naturally curtailed by completion of development or by parasites for no further counts were obtainable even in the untreated plots.

Although toxaphene and DDD were not significantly inferior, the results of the present tests indicate that endrin might well be considered as first choice for garden webworm control on small corn.

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[1] Accepted for publication December 16, 1954.

Chemical Control of the Corn Earworm in Sorghum Heads[1]

C. C. BURKHARDT and M. P. BREITHAUPT, *Kansas State College, Manhattan*

Numerous reports of damage by the corn earworm, *Heliothis armigera* (Hbn.), in grain sorghum (milo) heads were received in August 1954. Many fields in north-central Kansas were reported to have from 40 to 60 per cent of the heads infested with larvae ranging from 1 to 8 per head. In several fields examined in Riley County, 40 to 50 per cent of the heads were found to be infested with 5 to 16 larvae per head with many heads bearing 8 to 10 larvae, especially while in the first to third larval instar.

One of the sorghum heads containing 16 larvae was carefully examined and observed to have had 25 to 30 per cent of the kernels damaged or destroyed. Such losses in yield present a real economic problem to the farmers.

MATERIALS AND PROCEDURES.—The test plot was located on the College Agronomy Farm near Manhattan, Kansas. Nine different insecticidal emulsions[2] were tested as follows on a toxicant per acre basis: endrin at 0.4 and 0.6 lb.; heptachlor at 1.25 lb.; lindane at 0.4 and 0.5 lb.; toxaphene at 5 lbs.; parathion (0.5 lb. per gallon) in oil at ½ lb.; endrin (0.4 lb. per gallon) in oil at 0.4 lb.; OS-1808 and OS-2046 each at ½ lb.; and DDT at 2¾ lbs.

Although phosphate insecticides with systemic action when applied to leaves are generally associated with control of sucking insects, systemics OS-1808 and OS-2046 were included in the test because the corn earworms were difficult to reach with a contact insecticide.

Each plot, except the DDT plot, consisted of one 50-foot row of sorghum with the first 25 feet treated and the remaining 25 feet serving as a check. Two 25-foot rows, not adjacent, were used for the DDT plot, with one row treated and the other serving as a check.

The materials were applied with a Hudson 3-gallon hand compressed sprayer calibrated to deliver 1/10 of a quart of total emulsion per 25 feet of row at normal walking speed and at 30 to 40 pounds pressure. This is comparable to 46 gallons of total emulsion per acre. In the case of the oil solutions, 1 gallon of the insecticide-oil preparation was added to 45 gallons of water per acre.

The per cent control obtained was determined by carefully examining and recording the number of larvae found in 20 heads selected at random in each treatment, compared with the number of larvae in the corresponding adjacent check plot. Postspray counts were made at 24 and 96 hours.

The corn earworms were mostly fourth instar larvae at the time of treatment.

RESULTS.—Table 1 shows the per cent control obtained at 24 and 96 hours after treatment with nine different insecticidal formulations. The highest per cent control at the end of 24 hours was obtained with OS-2046 (96 per cent) followed by DDT (84 per cent). Whether control, in the case of OS-2046, resulted from systemic action, or from direct contact, or by fumigation (Corey *et al.* 1953), was not determined. Heptachlor and OS-1808 gave the lowest per cent control with 41 and 37 per cent, respectively. Control in the remaining treatments ranged from 60 to 76 per cent.

OS-2046 gave 100 per cent control 96 hours following treatment. Endrin at 0.4 lb., lindane at 0.5 lb., endrin in oil at 0.4 lb., and DDT at 2.75 lbs. toxicant per acre resulted in 95 per cent control. Endrin at 0.6 lb., heptachlor at 1.25 lb. and lindane at 0.4 lb. gave 90 per cent control.

Certain of the treatments showed a substantial increase in effectiveness at 96 hours compared with 24 hours, indicating slower action in some cases. This is an important factor because 2 additional days of larval feeding can materially reduce the number of grains in the sorghum heads.

Table 1.—Control of corn earworms in sorghum heads with insecticides near Manhattan, Kans. 1954.

INSECTICIDE	POUNDS ACTUAL TOXICANT APPLIED PER ACRE	PER CENT CONTROL	
		24 HOURS	96 HOURS
Endrin	0.4	68	95
Endrin	0.6	72	90
Heptachlor	1.25	41	90
Lindane	0.4	72	90
Lindane	0.5	64	95
Toxaphene	5.0	64	85
Parathion in oil	0.5	60	85
Endrin in oil	0.4	60	95
OS-1808	0.5	37	43
OS-2406	0.5	96	100
DDT	2.75	84	95
Check	—	—[a]	—[b]

[a] An average of 25.3 larvae per 20 heads.
[b] An average of 20 larvae per 20 heads.

Parathion and endrin in oil preparations were included in the tests in hope of increased penetration of the toxicants into the center of the head. Data indicate that the endrin-oil preparation was no more effective than the insecticide without the oil. Endrin at 0.4 pound toxicant per acre gave the same per cent control after 96 hours with or without oil.

Parathion at 0.5 pound in oil gave 10 per cent less control than 0.4 pound of endrin in oil.

OS-2046 showed slight phytotoxicity at the 0.5 pound rate.

SUMMARY.—Tests for the control of the corn earworm, *Heliothis armigera* (Hbn.) in heads of grain sorghum (milo) were conducted near Manhattan, Kansas with emulsions of insecticides at the following amounts of toxicant on a per acre basis: endrin at 0.4 and 0.6 pound, heptachlor at 1.25 pounds, lindane at 0.4 and 0.5 pound, toxaphene at 5 pounds, parathion and endrin at 0.5 and 0.4 pound in one gallon of oil respectively, OS-1808 and OS-2046 at 0.5 pound each, and DDT at 2.75 pounds.

OS-2046, a systemic insecticide, at 0.5 pound per acre gave 96 and 100 per cent control after 24 and 96 hours, respectively. DDT at 2.75 pounds toxicant per acre gave 84 and 95 per cent control for the same interval of time. OS-1808 effected poor control throughout the test. Although heptachlor at 1.25 pounds per acre showed only 41 per cent control at 24 hours, the 96 hour count showed 90 per cent control. The per cent control of other treatments ranged from 60 to 72 per cent after 24 hours and 85 to 95 per cent at 96 hours. OS-2046 at 0.5 pound showed some phytotoxicity.

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PAID PAPER.
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[2] Materials supplied as follows: endrin, OS-2046 (2-carbomethoxy-1-methylvinyl dimethyl phosphate) and OS-1808 (2-carbethoxy-1-methylvinyl diethyl phosphate) by the Shell Chemical Corp., Denver, Colo.; heptachlor by the Velsicol Corp., Chicago, Ill.; toxaphene by William Cooper and Nephews, Inc., Chicago 14, Ill.; lindane by Thompson-Hayward Chemical Co., Kansas City 8, Mo.; and DDT, parathion in oil and endrin in oil by Standard Oil Company (Indiana), Whiting, Ind. Oil was a refined, low viscosity, distillate oil.

EDITORIAL

Wanted—An Evaluation of Insects Losses

Most of the currently available information on the magnitude of agricultural and other losses attributable to insects is at best a compilation of estimates which may or may not deserve the title of "Educated Guesses." How long can entomology tolerate such a condition and still survive?

In reviewing the history of economic entomology one will find that from time to time outstanding leaders have called attention to the dire need for reliable quantitative data on insect losses and urged their fellow entomologists to take steps that would assure the development and eventual accumulation of such data. It would appear that for the most part these appeals have fallen on deaf ears. At least we have been content to drift along, relying upon crude estimates or guesses of questionable value as the basis for our answers to questions propounded by administrators, legislating bodies, and the public in general. Perhaps it is well that we do not know and can never determine the extent to which our conspicuous weakness in this regard has retarded the advancement of our profession and the science of entomology. We must recognize, however, that we have been handicapped and that unquestionably appropriations—state, federal, and industrial—for the support of entomological research might be much more generous than they are had our leaders been able to present documented facts and figures. Most certainly we are aware that a salesman with a well-documented prospectus can make sales more easily than one who relies largely upon unproved assertions and opinions. Likewise, a research worker or an administrator can get quicker and stronger support if he can present a verified and well-documented proposal. We glibly say commercial crops of most fruits and vegetables could not be produced without the use of insecticides, that the control of flies will increase milk and meat production by X per cent, but where are the irrefutable data required to convince the Congress, the farmer, and the skeptic?

The average American is fully aware of the presence of insects and has at least some idea of the many ways in which insects affect his well being, but he finds it difficult to accept at face value the somewhat vague and unverified assertions of the extension entomologist or the insecticide salesman regarding the extent of losses caused by insects. There is reason to believe that agricultural leaders and administrators in industry recognize this fact more clearly than the entomologists. For two consecutive years the Project and Proposals Committee of the Agricultural Research Institute, in its recommendations to the Agricultural Board of the National Research Council, has pointed out the need for a better understanding of various agricultural pest problems, and at the head of its list of proposed activities they state: "Reliable data on losses attributable to pests are sorely needed."

The Agricultural Board, acting upon the above suggestion, has established a Committee on Agricultural Pests. This committee in turn has set up five subcommittees on subject matter lines, and Dr. R. L. Metcalf of the California Citrus Experiment Station was designated Chairman of the Subcommittee on Entomology. The committee also gave first priority to a project, "The evaluation of losses attributable to agricultural pests." This project will be developed under the guidance of Dr. W. E. Loomis of Iowa State College, and each subcommittee will assemble data pertaining to its special problems. Dr. Metcalf's Subcommittee on Enomology will therefore be expected to assemble and develop the data on insect losses. It is expected the committee will have both immediate and long term objectives. It will first assemble all available published and unpublished quantitative data. In line with its long term objective, the committee will encourage the development of methods and techniques suitable for the accurate evaluation and measuring of insect damage or losses. Then, with techniques available, an effort will be made to induce all research workers and administrators to allocate at least a small yet significant portion of their time and available funds to projects that will contribute valuable data to the common pool.

The overall assignment represents a tremendous undertaking, one that very obviously cannot be accomplished by one or two, a dozen or even a score of men working alone. If this committee is to succeed, it will need to have the whole-hearted support and cooperation of every entomologist. Inasmuch as we have all, at one time or another, felt the critical need for better data on insect losses, why not resolve now to collect all locally available data and transmit it, together with all known citations to valuable quantitative data, to Dr. Metcalf and his associates. Then determine where and how we can, within the framework of existing or contemplated projects, make a significant contribution to the work of the Agricultural Pests Committee and resolve again to do our part. Needless to say, these resolutions will need to be more substantial and more enduring than the average New Year's resolution. He who at this point says to himself, "I will have to do something about this matter next summer," will in the end contribute little or nothing. Good intentions, to be effective, will have to be followed up by immediate concrete action.

The needs of the Committee on Agricultural Pests present a triple challenge: (1) The entomologists themselves have long recognized the need for more easily defensible statistics on insect losses, but have failed to band together in a common cause. Will they do so now? (2) Dr. Ross, in his Presidential address, drew attention to the interrelationships and the interdependence of all branches of science. Here we have a common problem being attacked; will entomology set the pace, lag behind, or fall by the wayside? (3) At times we as a group have been prone to criticize the National Academy of Science and the National Research Council for not giving greater recognition to entomologists and to entomology and its prob-

lems. Is it possible that we have been partly at fault? Have we failed to attract attention to our problems, our availability, or the potentialities of our members and leadership? In any case, the National Research Council has established a committee to look into some of our important problems. Individual members of our profession and our Society have been honored with important committee assignments. Those who have served on committees in the National Research Council or, for that matter, in any large national organization know that the whole-hearted support of their associates is essential to their success. Dr. Metcalf and his associates are unquestionably capable, but presumably they are not supermen and we have no right to expect them to acquire or demonstrate such attributes. Entomology is on trial and we, the individual entomologists, and we alone can influence the verdict. What will it be?

GEORGE C. DECKER,
Illinois Natural History Survey Urbana

SCIENTIFIC NOTES

Control of Army Cutworms in Alfalfa[1]

R. E. PFADT, *Wyoming Agricultural Experiment Station, Laramie*

Alfalfa fields in Wyoming are often infested in spring with army cutworms, *Chorizagrotis auxiliaris* (Grote). Usually populations are not uniformly distributed over large areas, but are concentrated in a limited number of fields. Early spring feeding of overwintered larvae on young shoots prevents the emergence of alfalfa above ground litter and causes fields to stay brown and wintry in appearance. Severely attacked fields remain brown for approximately 6 weeks after uninfested fields have begun to green.

Preliminary, unreplicated tests in 1953 explored the effectiveness of seven chlorinated hydrocarbon insecticides for control of the army cutworm (Pfadt 1954). In 1954 six of these plus two previously untested materials were used in the tests described below.

METHODS.—A uniformly infested alfalfa field in the irrigated North Platte Valley of eastern Wyoming was divided into three blocks of 12 plots each. Size of each plot was 36×72 feet. Nine treatments and three checks were assigned at random to each block. Because pretreatment sampling showed no significant variation in infestation throughout the field, percentage control was based on differences in cutworm counts between treated and untreated plots 14 days (average) after treatment.

Density of cutworms was determined by examining 10 randomly selected 1-square-foot areas taken diagonally across each plot. As several days were needed to complete the sampling, a regular routine was followed: First, 3 samples were taken from each plot, then 3 more, then 2, and finally 2 more to make 10. Sampling was carried out from the 12th to 16th day after treatments.

All sprays were made from emulsifiable concentrates and applied with a power sprayer. Fifteen gallons of spray under a pressure of 50 lbs. p.s.i. were applied per acre. Boom height of 18 inches gave complete coverage of ground.

In April at time of treating, the new growth of alfalfa varied in height from 0 to 1.5 inches and averaged 0.35 inch. Cutworms were judged to be mainly in the 5th and 6th stadia as based on measurements of head capsules. Weather data between treatment and sampling were the following. Temperature: Maximum range 31° to 85° F.; mean maximum 65° F.; minimum range 20° to 44° F.; mean minimum 32° F. Precipitation: 0.61 inch, the first rain (0.09 inch) falling 4 days after treatment.

Analyses for endrin residues were made on alfalfa sampled just before harvest of the first crop. Alfalfa was cut 2 inches above ground level from 21 stations per treated plot. The hay was then taken to the laboratory, cut into 1-inch segments, divided into 3 subsamples, packed in plastic bags, and shipped fresh to Shell Chemical Corporation, Denver, Colorado for analysis. Samples of alfalfa from untreated check plots were handled in like manner.

Table 1.—Control of army cutworm in alfalfa with eight chlorinated hydrocarbon insecticides. Huntley, Wyoming. May, 1954.

TREATMENT	POUNDS ACTUAL TOXICANT PER ACRE	MEAN NO. CUTWORMS PER SQ. FOOT	PER CENT REDUCTION 14 DAYS
Endrin	0.2	0.13	92
Dilan	0.25	0.23	86
DDT	2.0	0.33	80
Dieldrin	0.375	0.40	76
Dieldrin	0.25	0.87	47
Heptachlor	0.5	0.97	41
Chlordane	2.0	1.07	35
Toxaphene	2.0	1.13	31
Aldrin	0.5	1.27	23
Untreated		1.64	0
L.S.D. at 5% level		0.40	
at 1% level		0.54	

RESULTS.—The results of these tests are summarized in table 1. Four insecticides were most effective. In order of their effectiveness they were endrin at 0.2 lb., Dilan at 0.25 lb., DDT at 2.0 lb., and dieldrin at 0.375 lb. (6 oz.) of actual toxicant per acre. Dieldrin at 0.25 lb., heptachlor at 0.5 lb., chlordane at 2.0 lb., toxaphene at 2.0 lb., and aldrin at 0.5 lb. of actual toxicant per acre were significantly less effective in controlling army cutworms. Except for aldrin and dieldrin which were not tested in 1953, the results of 1954 corroborated those of the previous year (Pfadt 1954).

Application of dieldrin at 6 oz. per acre appears to have special merit, as both the alfalfa weevil (Hastings & Pepper 1951) and the army cutworm could be controlled in just one treatment.

No endrin residues were found on alfalfa treated with this toxicant at rates of 0.2 and 0.3 lb. per acre in 1953 or with 0.2 lb. per acre in 1954. The intervals between treating with the insecticide and cutting of samples ranged from 55 to 80 days.

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OBITUARIES

Charles Lester Marlatt

1863-1954

On March 3, 1954, a long, exceedingly rich and dynamic life drifted to a close. His work was of supreme importance in the development of economic entomology and its influence grows as time passes. Here was a man who possessed vitality and few, in his chosen field, had careers so full of movement and color. His personal life, his characteristics and the incidents which drew them out follow, in order that those who were not priviledged to know him and see him in action may have a glimpse, even though inadequate of this forceful character.

Charles Lester Marlatt was born in Atchison, Kansas, September 26, 1863. He was graduated from Kansas State College in 1884 with the degree of Bachelor of Science and two years later he received the degree of Master of Science from the same institution. In recognition of his contribution to American agriculture his Alma Mater in 1922 conferred upon him the honorary degree of Doctor of Science.

His professional career began in 1887 at which time he was made Associate Entomologist of the Kansas State College (originally chartered as Bluemont College in 1858 by a group of pioneers of whom his father was one) where he displayed among other things marked aptitude as an insect delineator. It was this unusual skill which influenced Dr. C. V. Riley to offer him a position in the Federal service which he accepted effective January 2, 1889. The description handed down of his arrival in Washington at the age of 25 calls to mind the following lines from Sir Walter Scott's "Marmion"

> "Oh, young Lochinvar is come out of the West,
> Throughout all the wide border his steed was the best;
> And save his good broadsword he weapons had none,
> He rode all unarm'd and he rode all alone.
> So faithful in love and so dauntless in war
> There never was a knight like the young Lochinvar."

It was quickly recognized that Dr. Marlatt was a versatile entomologist with qualities of leadership which could be used to greater advantage by the Division than his ability as an artist. Hence he was assigned a number of research projects which he completed with accuracy and dispatch.

In the early days of professional entomology in the United States the workers did not confine their interests to a single group or family of insects and Dr. Marlatt was no exception to this general rule. Thus we find that during the first 15 years of his professional life he published papers on insect oviposition, morphology, life history, hibernation, control and taxonomy. In the meantime (1894) he was made First Assistant Entomologist and Assistant Chief of the Division (Created a Bureau in 1904) which position was held until 1925 when he was promoted to Associate Chief. When Dr. Howard retired in 1927 Dr. Marlatt became Chief of the Bureau, adding this responsibility to the already heavy load carried as Chief of the Plant Quarantine and Control Administration. After serving approximately 2 years in this dual capacity, at his requrest, he was relieved of the responsibility of the management of plant quarantine enforcement in order that full time might be devoted to the administration of the Bureau of Entomology. He retired in 1933.

The literature of economic entomology contains numerous papers by Dr. Marlatt on insecticides and their methods of application, as well as insects affecting the household, including wood work of buildings, cattle, growing wheat, shade, forest, deciduous and subtropical trees. He was fascinated by the life history and habits of the periodical cicada and was the author of some 20 odd papers on this insect. The nomenclature of the different broods as we know them today was devised by him.

His adventurous spirit caused him, from time to time, to visit a number of foreign countries, largely at his own expense. The first of these was made in 1897 and the material collected was used in part in the preparation of his presidential address before the Entomological Society of Washington entitled "An Investigation of Applied Entomology in the Old World."[1] In summing up his observations in that region he stated, "In the matter of treatment of destructive insects it would appear, also, that we have little to learn or to gain from a study of the European methods, for the simple reason that injury is so much less frequent and less serious that wholesale and radical methods of control, such as are often necessary here, are seldom or never employed. This applies especially to the scale insects." He was of the opinion that this situation was influenced in no small measure by the European climate. In referring to his very pleasant call on the then well known dipterist in Vienna who was also in charge of the instructions in natural history at the Akademisches Gymnasium Dr. Marlatt states "On leaving him the writer was much surprised and not a little confused to be saluted with a most hearty kiss, a custom for which an American would hardly be prepared." In later years he made other trips to Europe and the results of his entomological observations were made available to various entomological societies.

An entomological exploration was made by him in Japan and China during 1901–1902 in search of the native home of the San Jose Scale, which was discovered in California in the early 70's and which subsequently gained wide distribution in the United States causing much injury to deciduous fruit trees and ornamental plants. This trip established two facts (1) that China was the native home of this pernicious insect and (2) that it was being held in check in Japan and China by the Asiatic ladybird beetle *Chilocorus similis* Rossi. Several shipments of this predator were made to Washington but unfortunately most of the specimens succumbed enroute, or during their first winter in this country. The story of the incidents associated with this trip is entertainingly told in his book, "An Entomologist's Quest" privately published in 1953.

An incident of vital importance to the welfare and future of Federal entomological work took place in 1902. In the temporary absence of the Chief of the Division the preparation and submission of the Annual Report fell upon Dr. Marlatt and in that report he submitted a plan of reorganization of the work on the basis of crops. This was accepted by the Secretary and the Appropriation Committee of the Congress in the Appropriation Bill of 1904, which also approved the elevation of the Division to Bureau status. This resulted in the new Bureau being divided into divisions and sections, an efficient and orderly organization of the work. This continued without interruption for 50 years. An attempt was made shortly after the turn of the century to merge entomology with plant industry much along the plan which was put into effect in 1953, but this earlier attempt failed because of the determined opposition of Drs. Howard and Marlatt.

Dr. Marlatt may be regarded as the father of the Plant Quarantine Act of 1912. Had it not been for his persistency, in the face of many discouragements this Act which has done so much to preserve American agriculture might have fallen by the wayside. On one occasion when informed that the Bill under consideration by the Congress was not acceptable he replied, "A new Bill will be introduced tomorrow." The Act as passed provided for a

[1] Proc. Ent. Soc. Wash. IV, 3, pp. 265–91 (1899).

Charles Lester Marlatt

Federal Horticultural Board and at the request of the Secretary of Agriculture Dr. Marlatt served as its first and only Chairman. His soundness of judgment and honesty of purpose resulted, with the help of the other members of the Board, in the establishment of a plant quarantine service second to none.

He played an important role in the eradication of the Mediterranean Fruit Fly from Florida—one of the outstanding insect miracles of the ages. He approached this problem almost at the "sunset" of his long and useful career. He accepted this challenge in his usual fearless way with eradication as the goal in spite of the fact that this destructive fruit pest had never been eradicated in any area in which it had become established. Displaying his customary ability to select the right man to do the job he placed Dr. Wilmon Newell, Plant Commissioner of the

State Plant Board of Florida, who was in complete sympathy with the eradication goal, in field charge. This unconquerable team eradicated the pest from 1002 properties within 18 months. Had this program been spearheaded by men of less determination than was shown by Drs. Marlatt and Newell, this destructive fruit fly might have remained with us as a permanent guest. It is men of this quality that make us proud of our profession.

More than a hundred publications, technical and of an economic nature, appeared under his name not to mention hundreds on the subject of plant quarantine. His honors include President of the Cosmos Club of Washington, President of the American Association of Economic Entomologists, President and Honorary President of the Entomological Society of Washington. He held the latter office at the time of his death. He was a fellow of the American Association for the Advancement of Science, and a member of the Kansas Academy of Science, Metropolitan Club, Chevy Chase and Burning Tree Golf Clubs, Gamma Sigma Delta and Phi Kappa Phi fraternities.

He is survived by Mrs. Helen Stuart Mackay-Smith Marlatt and four daughters, Miss Florence Marlatt, Mrs. Joseph K. Dickey, Mrs. Richard S. Huested, and Mrs. Halsted B. Vander-Poel.

In the words of Thomas Carlyle, "We cannot look however imperfectly, upon a great man, without gaining something by him."

E. R. SASSCER

Austin Winfield Morrill
1880-1954

The outstanding career of a pioneer entomologist has come to a close.

Dr. Morrill was a New Englander, a descendant of Abraham Morrill of England who settled in Cambridge, Massachusetts in 1632, and a relative of Justin Smith Morrill, author of the Land Grant Act of 1862 which provided for the founding and maintenance of agricultural colleges throughout the United States. Dr. Morrill was born in Tewkesbury, Mass., September 11, 1880, and died at his home, 460 West Longden Avenue, Arcadia, California, on September 28, 1954.

Austin Winfield Morrill

He grew to manhood in Massachusetts, where he attended public schools, and the Massachusetts Agricultural College (now the University of Massachusetts), graduating from the latter in the class of 1900. His early interest in entomology led to his entering the graduate school where he studied under Doctors C. H. & H. T. Fernald, R. S. Lull, and G. E. Stone, each a pioneer in research and teaching, and nationally known in their respective fields of entomology, zoology, and botany. During his collegiate course, he did original work with the greenhouse and strawberry aleyrodids which at that time were causing havoc in New England greenhouses, and with the pentatomid bugs, *Corythuca*, and the effects of fumigation upon plant growth. He was awarded the Doctor of Philosophy degree at M. A. C. in 1903.

In the spring of 1903 Dr. Morrill received an appointment in the Bureau of Entomology, U. S. D. A., and at once was assigned to Dr. W. D. Hunter, in charge of the newly established laboratory at Victoria, Texas, for the investigation of the cotton boll weevil and related cotton insects. This pioneer work with cotton insects continued until 1906, and included studies of the biology and control of the cotton bollworm, the cotton leaf worm, the conchuela, and other pests of cotton.

In 1906, Dr. Morrill was transferred to Florida and placed in field charge, under Dr. C. L. Marlatt, Tropical and Subtropical Insect Investigations, of the Bureau's Investigations of the aleyrodid pests of citrus, and established a laboratory at Orlando. Here assisted by E. A. Back, R. S. Woglum, and W. W. Yothers, much information was developed on the biology of citrus whiteflies, and their control by entomogenous fungi, spraying, and fumigation. Aside from the more general aspects of the investigations, Dr. Morrill paid special attention to developing a system of marking fumigation tents, and dosage tables whereby the cubic contents of tented trees, and the chemicals required for the fumigation of each tree could be quickly and dependably determined. This system, for which he was granted a public service patent in 1907, is today known as the "Morrill System" and is widely used in California citrus groves.

In 1909 he was appointed State Entomologist for the Arizona State Department of Agriculture, and Entomologist of the Arizona Agricultural Experiment Station. These positions he held until 1919. His ability, enthusiasm and skill resulted in the excellent organization for conducting research, teaching and extension entomology that has continued to develop in that State, and in arousing sentiment for quarantines for the protection of Arizona agriculture.

In 1920 Dr. Morrill began a notable career as a consultant in

entomology that was highly successful and a model for this type of work. Consultant service for the control of pests of tomatoes, peppers, beans, the truck crops and cotton insects was rendered the Mexican West Coast Vegetable Association (1920–1930) and the Southern Pacific Railway of Mexico (1921 to 1931). In connection with his work with the Association, he established at Los Mochis, Sinaloa, an experiment station of which he was director. Reports prepared covering his Mexican experience contain a wealth of entomological information. Of special interest were his estimates of crop damage likely to occur, based upon the numerical abundance of insects present early in the growing season, and his methods for estimating total insect populations in cultivated fields, based upon intensive counts over small areas.

By 1930 there had developed a great demand for *Trichogramma* parasites for use against cotton insects including the cotton bollworm, the leaf worm, the pink bollworm, and some insect pests of the peach. In response to this need, Dr. Morrill organized the California Insectaries, Inc., Glendale, California, in 1930, for the rearing and sale of these parasites. The business proved profitable and the parasites were shipped to many parts of the United States and to other countries. He served as president of this company until recent years and maintained an active interest in the parasite rearing work until his death.

During the period 1930 until his death Dr. Morrill continued to demonstrate his wide interest in entomology outside the activities of the insectary rearing and sale of *Trichogramma*. Included among these interests are the following: application of soil treatments and other methods of termite control; tests of effectiveness of fumigation of residential housing for control of dry wood termites; and making valuable contributions to the development of a code of ethics for pest control operators in California. He was an active member of the Los Angeles Chamber of Commerce, and served for several years as consultant for the City of Pasadena, California, in the development of improved building codes for protection against termites.

Dr. Morrill's memberships in scientific societies included the American Association for the Advancement of Science, the Entomological Society of America, the American Association of Economic Entomologists, and the Entomological Society of Washington. His bibliography includes many outstanding contributions to entomological literature. As a result of work with the U. S. D. A., and the State of Arizona he was the author of a number of bulletins and circulars pertaining to the biology and control of whiteflies and cotton insects. Papers were published also in the JOURNAL OF ECONOMIC ENTOMOLOGY, Proceedings of The Entomological Society of Washington, Transactions of the Florida Horticultural Society, and other journals until ill health brought a close to his successful career in entomology. More personal facts concerning Dr. Morrill may be found in "Who's Who in America," and in "American Men of Science."

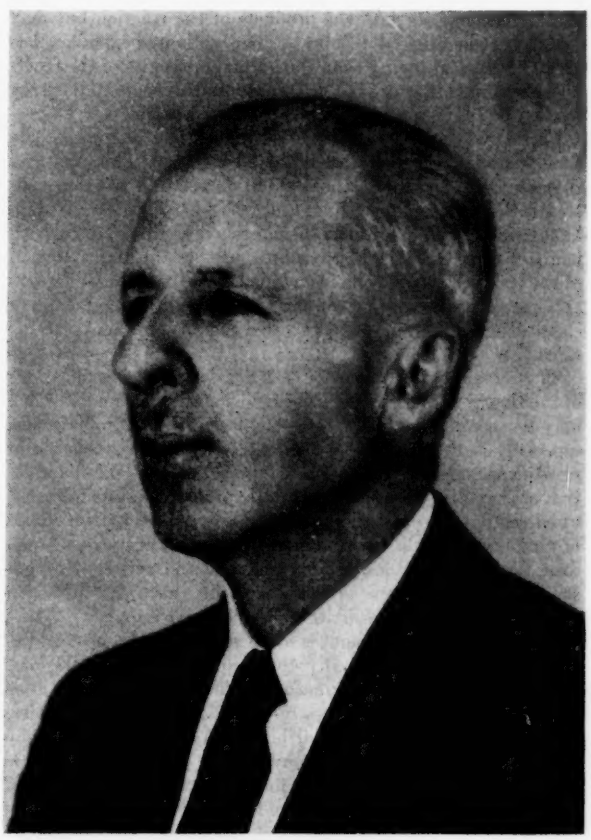
E. A. BACK
W. D. REED

George Haymaker Vansell
1892-1954

The many friends of Geo. H. Vansell, 62, were shocked by his sudden passing on October 22, 1954. Apiculture lost one of its foremost research workers. Van, as he was known to his friends, always had time to do the little things that made the world about him a brighter and better place to live in. A staunch friend and true neighbor, he was always ready to assist anyone with a problem. Integrity, modesty, simplicity and sincerity were the qualities that endeared him to his friends and commanded the respect of his scientific colleagues.

Vansell was a native of Muscotah, Kansas, and was educated at the Universities of Kansas (A.B., '15, A.M., '17), Harvard, California and Stanford. He began a teaching career in entomology and zoology at the University of Kentucky (1915–22) and continued at the University of California in entomology and apiculture (1922–31). In 1931 he began a research career at the U.S.D.A. Pacific States Bee Culture Laboratory, Davis, California. He was active at this laboratory on the day of his death, but looking forward to a new adventure on the Arizona desert at the Tucson Bee Culture Laboratory.

Van was a true naturalist. Those privileged to accompany him on field trips were treated to a stimulating experience. He was a keen and accurate observer, with a deep interest in all natural phenomena and a profound knowledge of plant and animal life. During his research span apiculture received its rightful recognition as an indispensable link in agriculture. Van's crop pollination research was the precursor of this marked advance in his chosen field. His studies showed that the sugar content of plum and pear nectars varied widely between varieties and field bees selected nectars of higher sugar content. This accounted for the lack of fruitfulness of some otherwise good varieties. These studies developed the basic concept that plants must compete for bee visitors and the poorer nectar sources are neglected. In 1942 when the nation's supply of legume seeds was critically short he began his alfalfa pollination studies. This work has resulted in the use of hundreds of thousands of honey bee colonies in the production of alfalfa and other legume seeds. By supplying pol-



George Haymaker Vansell

linators seeds can now be produced in localities where it was previously unprofitable and, in place of acute shortages, ample supplies are available for the farmers of the nation.

Among Van's other outstanding contributions to science and practice were: The composition of nectars and their influence on bee activity. The physical and chemical properties of beeswax which led to the use of aluminum wax rendering equipment and better quality of beeswax. The cause of adult bee losses due to California buckeye and the loco weeds, information now used by beekeepers to avoid contaminated areas. The use of electric fences to protect apiaries from bears' depredations. Among more than 100 scientific and popular publications on a variety of subjects, the honey plant bulletins for California, Oregon and Utah are probably the most basic. Van's ability to explain complicated data in simple language made him a welcome speaker at beekeepers' meetings and the author of numerous articles in bee journals. His influence on western beekeeping will long be felt and beekeepers of that area have lost one of their best informed and faithful workers.

Surviving Mr. Vansell are his wife, Jane Baird Vansell; two married daughters, Jane Vansell Holloway and Margaret Vansell Mattei; one son, Dr. Willis Vansell, D. V. M.; and 7 grandchildren.

FRANK E. TODD,
Entomology Research Branch, U.S.D.A.

BOOK REVIEWS

THE KINETIC BASIS OF MOLECULAR BIOLOGY. By Frank H. Johnson, Henry Eyring, and Milton J. Pollisar. 874 pp. John Wiley & Sons, Inc., New York City. Chapman & Hall, Ltd., London, 1954.

About twenty years ago one of the authors (H.E.) took a leading part in developing the method for calculating rates of reactions from only the physical properties of the reacting substances and the thermodynamic laws governing their behavior. This involved the notion of an intermediate molecule, the "activated complex," whose formation is essential for the reaction concerned, whose lifetime is extremely brief (about 10^{-13} second) and which usually decomposes into the products of the reaction but may revert to the original reactants. The activated complex has greater potential energy than the normal molecules of the reacting substance and hence is able to surmount the potential energy barrier, which separates reactants from their products.

Certain of these ideas have been applied to biology for some time, especially that of the activated complex. This was first suggested by Arrhenius whose equation relating reaction constants to the absolute temperature has been widely used in biological studies. Since most biologists will not be familiar with many of the concepts and procedures used in the major portion of the book, the authors have included six introductory chapters (122 pages in all) covering the fundamentals of thermodynamics, classical and quantum mechanics, and the calculation of reaction rates.

The remaining 640 pages of text are devoted to applications of the theory to the rates of various biological phenomena which may be separated into the following large fields: luminescence, especially in the Japanese crustacean, *Cypridina;* optimal temperatures, especially in protein denaturation and the inactivation of enzymes; effects of hydrostatic pressure and its influence upon cellular viscosity; inhibitors, as exemplified by the effects of various chemicals upon luminescence, effect of pressure upon drug action; inhibitors, and thermodynamic activity (Ferguson's rule); synergism and antagonism; narcosis; diffusion through membranes; cell irritability and nerve impulse.

The treatment throughout is mathematical, but a host of diagrams help greatly to clarify the treatment and conclusions. Biophysicists and others of mathematical bent doubtless will be interested in the highly successful applications of mathematical analysis to many fundamental biological problems, and biologists, including entomologists, may profit at least from the general process by which some of their fields of research are organized into quantitative form. And if the formal development is not of interest, there are scores of short discussions concerning all manner of biological phenomena. Perhaps three taken at random will illustrate these. On page 23 there is a discussion of templates and the formation of biological molecules. Since there is no advantage of laevo molecules over dextro, the general laevo character of critical biological materials is an argument for a primordial master template, which determined this matter. Life did not arise often by independent events for in this case laevo and dextro forms would be equally frequent. On page 465 is the statement based on a foregoing discussion of the influence of pressure upon drug action to the effect that drunks might be sobered at once by applying a hydrostatic pressure of 2000 to 3000 pounds per square inch. On page 466 is a discussion of the effect of temperature upon the toxicity of DDT to various insects and an interpretation of its negative temperature coefficient when externally applied as due to greater ability of the integument to hold DDT at low temperatures.

This volume represents a stupendous effort in assembling information, organizing it for mathematical analysis and drawing both particular and general deductions therefrom. It also is an excellent introduction to an enormous literature and deserves a place on the study table of everyone who seeks to understand the increasing fusion of biological, chemical, physical, and mathematical researches.

W. M. HOSKINS
University of California, Berkeley

FREAKS AND MARVELS OF INSECT LIFE. By Harold Bastin. Foreword by Frederick Laing. 1954. 248 pp., 20 pls. A. A. Wyn, Inc., 23 West 47th St., New York 36, N. Y. $3.75.

This book is written for nonprofessional readers primarily, but it is useful in professional libraries for occasional reading and for use when a nontechnical book is needed for the general public. There are 22 chapters, the first being an introduction which encompasses a brief but adequate review of the essentials of anatomy, biology, classification and nomenclature. The following examples are indicative of the subject matter of later chapters: Leaf folders and rollers; Giants and dwarfs; Insects that wear masks; Insects in winter; Nests and nurseries; Our insect friends and foes; What mimicry means.

Despite the book's title, much substantial information additional to that concerning "freaks" is contained, so that the treatment is balanced and generally informative. Unlike an earlier book of comparable title, "Marvels of Insect Life" by Edward Step, the present one is well organized and each chapter is a cohesive discussion. The author is well known in England for popular writing on scientific subjects, in fact many of his photographs of insects were used in Step's book, a few of which are here used again. The 20 plates of excellent photographs are sup-

plemented by a moderate number of sketches interspersed through the text. The book is well made, thoroughly bound, and has a colored frontispiece.

Although there are no citations of literature, the author shows a commendable familiarity with original works, and I have not noted any obvious inaccuracies. Scientific names are omitted from the text, but are grouped in a glossary of species names at the back of the book, together with a short index. Among the insects discussed, the majority of those inhabiting temperate areas are British, but a host of exotic examples which are conspicuous in one way or another are also discussed. The book is clearly and interestingly written, and it is a genuine credit to any shelf of popular entomological works. It is recommended to entomologists with general interests or those who need books to use in their work with amateurs and the lay public.

ASHLEY B. GURNEY

A CRITICAL REVIEW OF THE WORLD LITERATURE ON THE LEPIDOPTEROUS STALK BORERS OF TROPICAL GRAMINACEOUS CROPS. By W. F. Jepson, Commonwealth Institute of Entomology, 41, Queen's Gate, London, S. W. 7. 1954, 127 pp. Price 15/-(U. S. $2.25) post free.

This bulletin presents a summary of the studies which have been made in many parts of the world on lepidopterous stalk borers that are injurious to the tropical food crops, sugar-cane, sorghums, rice, and millet. Insects discussed are members of the lepidopterous families Pyralidae, the common genera being *Diatraea, Proceras, Chilo, Chilotraea, Scirpophaga,* and *Schoenobius,* and Agrotidae of the genera *Sesamia* and *Busseola.* The family Eucosmidae (gen. *Argyroploce*) is occasionally represented and the family Castniidae by the single species *Castnia licoides.*

It fills the need for an up-to-date, critical review of the research on this important group of insects and should help unite the problems in different areas which have hitherto tended to be unrelated to one another.

Instead of trying to cover a vast field represented by the many references in the "Review of Applied Entomology," the author used discretion born of his own experience with the group and gave weight to a smaller number of authors. This, plus further restricting the discussion to those borers of greatest economic importance, has resulted in a compact but detailed report most useful to the economic entomologist. The work is unusually interesting and thought-provoking as the opinions of various workers, along with comments by the author, are often presented on the same or similar problems. The lack of facts, conflicting experimental data by different workers, and need for more definite and conclusive information is stressed in some instances.

The book contains a preface, introduction, and eight sections. The first section is historical and lists the principal stalk borers of various regions. Section 2 points to the useful systematic work which has been done during the past 20 years and reviews briefly the main characters for identifying different species. Section 3 has to do with host-range and contains a table giving host-plants of economic importance. Section 4 is on bionomics. Section 5 is concerned with methods of estimating borer populations and crop damage. Section 6 deals with the relation of borers to cultural practices. Section 7 is devoted to the role of natural enemies of the borer as a cause of population fluctuations, and section 8 has to do with cultural, varietal resistance, chemical, and biological methods of control. Conclusions and recommendations for future research along with 10 pages of references and indices to names of insects and plants round out the work.

RALPH MATHES
Entomology Research Branch, U.S.D.A.

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